FRUIT COMPONENT AND SEEDLING PROGENY ANALYSIS OF KOMADAN COCONUT TYPES

By

P. MANJU, M.Sc. (Ag.)

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DECLARATION

I hereby declare that this thesis entitled "Fruit component and seedling progeny analysis of Komadan coconut types" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellayani,
14-1-1992.

P. MANJU.

CERTIFICATE

Certified that this thesis entitled "Fruit component and seedling progeny analysis of Komadan coconut types" is a record of research work done independently by Smt. P. MANJU under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Vellayani,
14-1-1992.

Dr. R. Gopimony,
Chairman
Advisory Committee,
Professor of Plant Breeding,
Communication Centre,
Mannuthy, Trichur.

APPROVED BY

CHAIRMAN

DR. R. GOPIMONY

MEMBERS

DR. V. GOPINATHAN NAIR

DR. K. U. K. NAMPOOTHIRI

DR. S. RAMACHANDRAN NAIR

DR. (MRS.) P. SARASWATHY

27/1/92

EXTERNAL EXAMINER

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

1.INTRODUCTION

Coconut (Cocos nucifera L.), the best known tropical palm of majestic nature and features providing food, drink and shelter to millions of people in South and South-East Asian countries, is known to occur in India from post Vedic periods. Eventhough the centre of origin of this monotypic species is not known for certain, its centre of diversity is definitely known to be located in the South-East Asian and Malaysian regions. The varietal diversity of this crop in India is very much limited since it was introduced from its centre of diversity through human migrations in prehistoric times.

Since Kerala occupies a pivotal position with regard to antiquity, area and production of coconut in India, detailed studies on the origin and genetics of the local coconut types will help to develop new breeding systems for this perennial tree crop. Unfortunately such studies are meagre and mendicant on some prominent cultivars like West Coast Tall, Kappadam and various dwarf types. It was under these limitations of coconut research on varietal diversity and identity, that the present study was undertaken to decipher the myths and mysteries behind one local coconut type called Komadan which is very popular in the erstwhile Central Travancore region of Kerala for the last many decades.

The first record on this variety was seen in the old crop plan register of the Instructional Farm of College of Agriculture, Vellayani which is the second major campus of the Kerala Agricultural University. According to this register 50 seedlings of a new coconut type called Komadan was brought from Thiruvalla by Sri. John, the then Superintendent of the Farm and planted in a contiguous plot in the 'D' Block of the Instructional Farm during 1957. These palms were seen grown to maturity and started yielding from the fifth to eighth year of planting as per details in the coconut harvest register in the Farm. These palms were seen giving an average of 112 nuts per tree per year in 1970 itself. The higher productivity of the palms in comparison to the West Coast Tall trees growing in the same block has attracted the attention of the officers in charge of the farm and it is seen from the records that these Komadan palms were used for collection of seednuts from 1977 onwards for producing quality coconut seedlings for distribution to farmers as a separate variety. The fact that Komadan seedlings were sold at a higher price compared to ordinary WCT seedlings from the Instructional Farm, Vellayani justifies the higher esteem to which these palms were regarded by the authorities concerned. On an average 7000 seedlings of Komadan were being sold out to public every year from 1978 onwards. Unfortunately no one thought it essential to justify the scientific propriety of putting a higher price tag to Komadan seedlings over the WCT ones. As years passed the demand for Komadan seedlings has increased to such a high level that the authorities were forced to regulate the supply through prior booking and ceiling on the allotment of seedlings to individuals. An interesting fact about the growing popularity of Komadan coconut among the farming community of Kerala is that it is purely based on this personal experience over the performance of the second and third generation Komadan palms growing in and around the Vellayani campus of the Kerala Agricultural University.

The first published record on Komadan coconut type is that of Gopimony (1982) who has conducted a preliminary study on the population structure and seedling progeny of Komadan in comparison to West Coast Tall. He has suggested in his paper that Komadan is a superior coconut off-type deserving further research attention. But some scientists are of specific opinion that the Komadan types available at Thiruvalla Taluk in Central Travancore region of Kerala are only natural hybrids of Chowghat Dwarf Orange x WCT (Pillai, 1991).

The present study was undertaken to straighten the above dichrotic view and to unravel the genetic status of Komadan in relation to its origin through fruit component and seedling progeny analysis. The methods used for this study and the results obtained are presented and discussed in this thesis.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

In the year 1916, when the first Coconut Research Centre in the world was established simultaneously at Nileswar, Kasaragod, Padannakad and Pilicode, South India, the scientific enquiry into the mysteries of one of the most useful and beautiful trees in the world was initiated. The early works were mainly on the morphological and floral biological aspects. The research work on coconut in the country picked up momentum in the 1940s with the establishment of more centres within and outside the country. An overview of the voluminous literature on origin, variation and breeding of coconut accumulated during the last five decades are presented below.

2.1 Origin of coconut

Few plants are more widely distributed in nature than the coconut palm, which is found throughout the tropics whereever local conditions are favourable. Guppy (1906) was of the opinion that the coconut originated on the Pacific coast of tropical America, whereas Cook (1910) favoured an origin among the Cocoid palms in the valleys of the Andes in Colombia with subsequent dispersal by primitive people to the Islands of Pacific and Indian Oceans. Ridley (1930) also suggested a tropical American origin in his treatise 'The dispersal of plants throughout the world'. Heyerdahl (1950, 52) from his famous Kon-Tiki expedition showed that coconuts could have been taken from South America to the Tuamotu Archipelago in the South Pacific on a raft of balsa wood. Corner (1966) opined a southern migration via Antartica, supported by the discovery of fossil nuts in the form of small coconuts in the late Tertiary (Miocene-Pliocene) beds on North Island, New Zealand. Purseglove (1968) agreeing with an Indo- Pacific origin suggested that the most numerous relatives of the coconut are the Cocoid palms, originally placed in the genus Cocos, in north western South America. Its ancestor with fibrous mesocarp enabling it to float and establish under suitable conditions could have been carried by ocean currents from South America to Polynesia.

Grimwood (1975) while reviewing the literature on origin suggested that there are two schools of thought on the origin and subsequent dispersal of coconut. The first expounds a New World origin with subsequent dispersal to Polynesia and Asia.

2.2 Varietal diversity

Taxonomic studies and investigations of monocotyledon anatomy show *Cocos nucifera* to be monotypic. However, different varieties and cultivars are recognized.

John and Narayana (1949) recognized five different varieties.

i) Typica-tall bearing palms with both male and female flowers.

ii) Nana-dwarf, delicate palms bearing in 3 years.

iii) Javanica-dwarf palms bearing in 4 years.

iv) Spicata-tall palms with unbranched inflorescences or inflorescences having one or two small spikes only.

v) Androgena-with male flowers only.

Fremond *et al*. (1966) divided the coconuts into 2 groups, the allogamic or cross pollinating coconuts and the autogamous or self pollinating ones. Various studies revealed that no clear division can be made between allogamic and autogamic coconuts and that there are several forms in between showing that this classification is not ideal either (Rognon, 1976.)

Harries (1978) identified two main groups of coconuts, the "Niu kafa" that evolved naturally, and the "Niu vai" that arose under cultivation. He opined that dwarf varieties have been selected and maintained in cultivation by man. The Niu kafa has the capability of being disseminated by floating in the sea and to sprout on the beach where it has been thrown onto, without rolling down into the water again. Such palms have relatively few, large, angular shaped slow-germinating fruits with thick husks, spindle-shaped nuts with thick shells, and thick dense endosperm with a high oil content. The Niu vai palms carry more fruits which are round, have thinner shell,thinner husk and germinate earlier.

Harries (1982) reported that the recently introduced Niu kafa-Niu vai Introgression (NKNVI) method compares similar varieties and contrasts different ones, irrèspective of where they come from and the conditions under which they grow. It is desirable, where possible, to apply the NKNVI method to actual measurements taken from many individual palms in the population to be studied. The common tall coconuts in India are predominantly Niu kafa types. The Niu vai type is also present but less common and introgressing between the two forms is evident.

Rao et al. (1983) reported that in all the ten cultivars studied, leaf and inflorescence characters and fruit components were found to be consistent between the locations for within a population but stem characters were highly variable. The Andaman Tall and Benaulim were falling in two separate clusters while all the rest of the Tall populations formed into a single large cluster in the D^2 analysis based on fruit components.

Balakrishnan and Namboodiri (1987) reported that the 24 cultivars studied fell into six different clusters based on the genetic distances among them. Cultivars of the same place of origin fell into different clusters while those of diverse origin fell into the same cluster. The clusters showing maximum diversity (clusters IV and VI) came under the Niu vai and Niu kafa types, thereby confirming that there is wide range of genetic variation between clusters IV and VI.

Harries (1991) stated that the concept of introgressive hybridization explains how the variability observed in plant populations, such as coconut in India or elsewhere, has risen and how it affects choice and selection of hybrid parents. The effects of introgressive hybridization can be observed in many aspects of the palm's performance. The introgressed populations can be classified as either predominantly wild type or predominantly domestic type. In India the wild type characteristics predominate.

2.2.1 Tall varieties

West Coast Tall (WCT) coconut is grown in large numbers on the West Coast of India. It is a hardy palm, yielding copra, oil and fibre of good quality. But its population is highly variable. Nuts vary in size, shape and colour. It has generally a medium yielding capacity. Since the last half a century, more than 95 per cent of the coconut area in Kerala continues to be cultivated under this local variety. WCT is a locally adapted plant type with considerable genetic variation for yield of nut and copra. During a survey conducted to study the performance of coconut hybrids in the cultivators' fields in Kerala, it was found that under identical conditions of poor management, WCT performed far better than the hybrids (Kannan, 1982). WCT has been reported to be a stable cultivar (Balakrishnan _et al_., 1991a).

Andaman Giant found on the Andaman-Nicobar Islands is a very strong and robust palm, exhibiting gigantic morphological features. The nuts are very large and more or less round with thin endosperm. The copra content is only 190 g/nut and the oil percentage is about 66 (Ohler, 1984).

Kappadam is another tall variety from the West Coast of India with large nuts, one of the largest on record (Gangolly et al., 1957). The fruit is ellipsoid and it has a rather high content of thick and hard copra. The nut yield is rather low. It is not stable in annual yield due to its biennial (alternate) bearing tendency (Balakrishnan et al., 1991a).

Laccadive ordinary or Laccadive tall commonly grown in the Lakshadweep Islands of India is more or less similar to West Coast Tall, except for its high oil content of the copra (72 per cent), more number of medium sized nuts and high outturn of copra. The female flower production and the setting percentages are also high (Ohler, 1984).

Komadan is a local coconut off-type, popular in the erstwhile Central Travancore area of Kerala associated with the family history of an old 'Tharavadu' called Komattu House. Gopimony (1982) reported that Komadan was superior to WCT in morphological characters of the palms including nut and copra characters in a preliminary observation done on the available Komadan palms in the Vellayani campus of Kerala Agricultural University. This study also indicated the overlapping nature of male and female phase suggesting a self pollinated breeding system in this local type. Local enquiries made at the centre of origin of this coconut type, revealed that a curious process of shrewed selection for yield linked phenotypic characters like bronze colour and oblong shape of nuts was conducted for many generations (Shylaraj et al., 1991). They also opined that Komadan type further exhibited superior seedling vigour in terms of germination per cent, height, collar girth, mean number of total leaves and mean number of split leaves when they compared Komadan mother palms and seedlings with those of West Coast Tall.

2.2.2 Dwarf palms

Laccadive dwarf found on the Lakshadweep Islands of India yields less than 50 nuts per annum. The copra content is about 115-145 g per nut and the oil content is about 71 per cent (Gangolly et al., 1957).

Ayiramkachi a dwarf palm, found on the East Coast of Tamil Nadu is a heavy yielder with very small oblong nuts. Satyabalan (1982a) considered this palm as intermediate between tall and dwarf. The nuts are green and the copra is of good quality. It has a high female flower production which may be exploited for breeding purposes. However, it is an alternate bearer (Ohler, 1984).

Chowghat green and orange are other dwarf cultivars found in the central region of Kerala. Chowghat green cultivar with dark green nuts has a very high female flower production but with a low setting percentage. Its copra is of very low quality with a low oil content. Chowghat orange cultivar produces medium sized orange coloured nuts having a copra content of about 135g and the oil content as low as 55 per cent or less ((Nelliat, 1978). Unfertilized female flowers are retained on the spikes, being characteristic of these varieties (Ohler, 1984).

2.2.3 Intermediate varieties

Rao and Koyamu (1955) reported that Gangabondam variety has characters which resemble those of the tall. According to Gangolly et al. (1957) Gangabondam belongs to the medium dwarf or semi-tall type with about 230g of copra per nut and a high oil percentage of 72. Ratnam (1968) reported that this variety comes from the East Godavary District in Andhra and it breeds 95 per cent true to type. Nelliat (1978) reported that Gangabondam has a copra content on about 150g per nut.

2.2.4 Natural Cross Dwarfs

Some dwarf varieties were known to throw a proportion of `semi-tall' progenies. Jack and Sands (1929) consider that such progenies are hybrids resulting from natural crossing of dwarfs with talls. This has been observed in the Malayan dwarf green and Chowghat dwarf orange and green (Satyabalan, 1956). Studies on such off-type progenies of dwarfs carried out at Kasaragod have shown that the off-types, particularly those of the Chowghat dwarf orange are early and prolific bearers compared to the dwarf parental types, the tall (female) x dwarf (male) hybrids and the West Coast Tall (Ninan and Satyabalan, 1964). Pillai (1991) reported that the natural hybrids obtained from Chowghat orange dwarf were till recently known as Natural Cross Dwarfs and that in Central Kerala, these hybrids are known by the name Komadan. He opined that the percentage recovery of hybrids (DxT) greatly depends upon the level of homozygosity of the dwarf and tall parents involved in crossing.

2.3 Selection and breeding

A three stage selection programme is most effective in improving coconut viz., selection of mother palms, selection of seednuts and selection of vigorous seedlings. Fremond et al. (1966), Apacibla and Mendoza (1968), Silva and George (1970) and Kannan and Nambiar (1979) firmly concluded the need and applicability of this three tier selection programme.

According to Harries (1979) successful natural evolution of the Niu kafa type must depend on its fitness. Fitness is lost under cultivation. Under cultivation, selection has diverged to produce some types in which nut size is favoured at the expense of nut number or vice versa.

Harries concludes that genetically nut number and size are quantitatively controlled. All, or most of these must be retained in the Niu kafa genotype whereas the genotypes of cultivated forms will be depleted by the loss of genes for one or another, depending on the direction and intensity of selection. A much more important change having been achieved under cultivation is the nut composition where a shift from heavy husk and heavy shell to heavy copra content has occurred.

Shylaraj (1982) opined that emphasis should be towards a systematic Triphasic Selection Schedule. In the initial phase, select prepotent mother palms on the basis of the expressed early progeny performance in terms of generalized vigour from among a lot consisting of apparently healthy trees yielding not less than 100 nuts per year.

Selection and breeding are mainly aimed at higher yield and precocity but also at resistance to diseases and pests and tolerance to unfavourable conditions. Copra is considered to be the most important part and yields are expressed in the quantity of copra produced per hectare (Ohler, 1984).

2.3.1 Mother palm selection (Mass selection, maternal or maternal line selection)

Early selection work in coconuts was primarily based on mother palm and nursery selection. Such selections were based on phenotypic expression which as such, is unreliable. Nongenetic factors such as site-specific favourable growing conditions, heterosis effect or alternate bearing habit may influence the appearance of the palm (Ohler, 1984).

Jack (1930) suggested that it is possible to bring about improvement in coconut culture through the application of a scientifically based mother palm selection procedure. He estimated that by mother palm selection alone, the first generation performance could be enhanced to the order of 25 to 35 per cent, irrespective of any knowledge or identity of the pollen parent.

Smith (1933) suggested a method for the selection of economically more desirable mother palms based on the per tree annual yield of nuts and the wet meat content in the nuts. Further, importance is given to the size of individual nuts as well. It was also pointed out that palms bearing an annual yield of not less than 100 medium sized nuts with a mean per nut wet meat content of 500 g at least, alone need be chosen for the purpose of collecting seednuts.

Peries (1934) specified the following attributes as reliable and important for selection.

a. Stout straight stem with closely spaced leaf scars

b. Short and well oriented fronds in the crown which itself should carry a larger number of leaves and inflorescence

c. Short bunch stalks having no tendency to droop and

d. Good number of female flowers in each inflorescence preferably a number ranging up to 100.

Liyanage (1953) stated that palm improvement in coconut could be effected to an additional 50 per cent efficiency by mother palm selection alone. The efficiency could be raised even upto 90 per cent or above through permitted open pollination among selected palms grown in isolation.

Liyanage (1958) observed that when seednuts were taken from high yielding palms, low yielding palms and from the heap, the differences in yielding capacity of the progenies turnedout to be very small and insignificant. The progeny of the low yielding palms produced the highest number of nuts per palm and had a high average copra content per nut than the other groups. It was concluded that phenotypic mother palm selection is not effective as a means of genetic improvement. Apparently all mother palms selected had been selected on a phenotypic base only and their good performance was not the result of genotypic superiority. Estimates of heritability for yield of nuts have shown that it is about 0.5 (Lakshmanachar, 1959 ; Liyanage and Sakai, 1961 ; Nambiar and Nambiar, 1970) indicating that selection of mother palms on the basis of yield of nuts alone is not likely to give the expected results.

Marar (1960) recommended confining selection of mother palms to gardens in reputed coconut growing areas alone. Only superior yielders, giving per tree mean nut yield of around 100 per year, with regularity in bearing, maintaining healthy and vigorous looks, characterized by thick set spherical crowns, short thick leaf stalks and stout bunch stalks and medium sized, nearly round nuts should be selected. Trees growing in specifically favourable stray environmental pockets and those producing barren nuts should be eliminated.

Marar and Shambhu (1961) suggested a simpler method to facilitate initial screening of mother palms by noticing the posture of seednuts floated on water. Those that remained vertically erect were found to develop into more vigorous seedlings than those that remained oblique or horizontal.

Liyanage (1962) proposed inclusion of characters like number of bunches produced per year, number of nuts per bunch, weight per husked nut, number of female flowers per bunch and setting percentage, while formulating a satisfactory complement of reliable criteria for mother palm selection in coconut. The other criteria valid in this regard are earliness in bearing initiation and yield of nuts especially when an increase in copra production is expected of the progeny. He was the first to rely upon a multiple criteria approach for effecting selection of mother palms in a more scientific and dependable manner. Accordingly, a formula of the said index was formulated as follows.

$I = X_1 - 14.70\ X_2 - 4.47\ X_3$ where,

X_1 = number of nuts per palm per year

X_2 = weight per husked nut (lbs)

X_3 = flowering period of palm (months)

Pankajakshan et al..(1963) on the basis of a study conducted for a continuous period of four years, recommended selection of palms characterised by a higher value for the mean of the quantified yield factor with a low and steady value for standard deviation. Further, they pointed out that a percentage increase in efficiency to 79 could be achieved in the selection of mother palms by restricting selection to the best 10 per cent palms in a standing population. This benefit in terms of percentage could be enhanced to even 100 per cent, if the proportion of palms selected is to a still lower percentage of around five.

Liyanage (1964) carried out mass selection on a sample of 104 individuals in favour of nut weight and selected the best 10 per cent and consequently genetic gain to the extent of 12.8 per cent was attained. The total number of leaves produced during the first 40 months and yield of nuts at the 13th to 14th year, exhibited significant positive correlations. Hence, the leaf production expressed numerically during the early growth period of the palm is believed to serve advantageously in assessing the future yields.

Apacible and Mendoza(1968) opined that for the choice of superior mother palms, seednuts and seedlings emphasis is given in favour of steady average bearing nature among palms belonging to a group yielding not less than 100 nuts per year, comparatively heavier medium sized spherical or near spherical seednuts, and relatively taller, one year old seedlings with noticeably greater girth at the collar and presence of more number of split leaves.

Tammes and Whitehead (1969) considered five years of yield recording necessary for accurate yield estimation to allow for biennial or polyannial differences. They are also of the opinion that harvest records are only valuable after the twelfth year of age, though earlier records may be of much help in the interpretation of later data.

Zuniga et al. (1969) selected potentially high yielders in three coconut plantations. They put forward recommendations in favour of a three year yield study, sufficient to predict the yield potential of parent palm, provided only 5-10 per cent of the best trees were selected.

Abeywardena (1970) reported that a survey of the pre-experimental yield pertaining to two years could enhance the degree of accuracy to more perfection than what was the case with a single year's data.

Manthriratna (1970a) opined that substantial increase in yield can be obtained by selection of seed parents in favour of heavier husked nuts, followed by a further rigid selection of seedlings in the nursery.

Balingasa and Caprio (1977) stressed the need to take up production and quality of nuts into consideration during the mother palm selection. Preference is given accordingly to palms that produced greater number of nuts with increased meat contents.

Kannan and Nambiar (1979) studied the influence of mother palm and seedling selection on the performance of progenies and emphasised the unsuitability of palms yielding less than 20 nuts per year for seednut collection.

Abeywardena and Mathes (1980) presented an index for selecting vigorous seed parents, based on the characters

(1) trunk girth below the crown (2) number of opened inflorescences (including mature bunches) (3) average number of nuts per bunch and (4) number of green fronds at any one time.

Louis (1981) studied the phenotypic and genotypic variability in 25 varieties and hybrids and found number of leaves/year, number of leaves on the crown, number of spathes per year, number of female flowers per palm, setting percentage and number of nuts to have high genetic advance and recommended consideration of these characters for exercising selection. Moderately high genetic advance was combined with moderately high heritability for the length of the leaf and number of leaves in the crown indicating the predominance of additive genes, which was considered a desirable feature for selection.

Gopimony (1982) pointed out that regarding the average nut yield, 99 per cent of the Komadan population gave more than 80 nuts per tree per year while only 15 per cent of WCT gave the same yield. The mean values of morphological characters also showed superiority of Komadan for all the nine quantitative characters studied. He further opined that since Komadan is considered to be of self pollinated nature, it is assumed that the prepotency carried by Komadan types will be transmitted to its progenies.

Satyabalan (1982) concluded that hybrid performance depends on the combining ability of the parents used and that these should be selected for high numbers of nuts with high copra content.

Shylaraj (1982) in a study to identify prepotent mother palms of Komadan observed that the tree should have a globose crown with around 35 fronds which are so aligned so as to avoid mutual shading and to facilitate convenient accommodation of bunches.

Mathew et al. (1984) reported that the super mother palms are significantly superior to control mother palm in relation to two mother palm characters viz., number of bunches and number of nuts per bunch. These two types of palms were on par with respect to other seednut and seedling characters. Medium to high GCV and PCV have been obtained for weight of unhusked nut, husked nut and meat, thus offering scope for formulating selection on the basis of these characters.

Ohler (1984) reported that mother palms were selected "on sight" within a population in Mosambique, the average yield of which was about 40 nuts per palm per year. Three of the selected palms yielded 160-175 nuts per palm per year during three consecutive years, or about four times as many as the general average. He further reported that number of nuts per year showed a moderately high phenotypic coefficient of variation and a moderate value for heritability and the expected genetic advance was rather low. It was concluded that non-additive gene action was low for this character, and that a selection strategy for yield of nuts might be indirectly based on component characters, such as number of leaves produced, number of leaves on the crown, number of spathes per year and number of female flowers with high setting percentages.

Chadha and Rethinam (1989) reported that for more number of good quality seedlings, rigorous re-selection of existing mother palms and selection of additional palms in the farmers' garden based on yield performance and collection of seednuts from all the selected standard mother palms should be exercised.

Ramanathan (1989b) reported that in a random selection of 5 per cent of mother palms which were open pollinated, 60 per cent of the palms chosen were found to have the ability to transmit the yield potential resulting in progenies with yield increase ranging from 41.5 per cent to 95.8 per cent over the parental yield.

Bourdeix et al. (1991b) reported that the initial results from six trials made it possible to estimate a genetic gain of 20 to 30 per cent for selection of the best 7 to 8 per cent of parents. The progress achieved is basically due to improvement in the number of nuts. Prior phenotypic selection within the ecotypes seems to be effective, but cannot replace the progeny test.

Liyanage (1991) opined that selection of seed parents of short internode length, high setting of female flowers into fruits, weight per husked nut and copra per palm brings about genetic progress in the progenies.

Louis and Rethinakumar (1991) stated that though selection continuously removes the deleterious mutant genes in the population,linkage, inversion and continuous mutation are assumed for building up and maintaining heterozygosity within this limited genetic load in coconut.

Mathew and Gopimony (1991b) based on the study of linear relationship between seedling vigour index and seedling characters concluded that while selecting mother trees, more emphasis has to be given to weight of husked nut and meat.

Ovasuru et al. (1991) reported that nut production and number of female flowers per spadix are more variable than other characters as shown by very high coefficients of variation.

Pillai et al. (1991) reported that there is not much variation in the number of female flowers produced in an inflorescence between cultivars. They further observed that the dwarfs had overlapping of the male and female phases within an inflorescence resulting in self-pollination while all the talls are cross-pollinated. This trait is useful in the identification of cultivars.

2.3.2 Correlation studies on mother palm characters

Liyanage (1967) pointed out that a significant positive correlation was found between leaf production and the mean yield of the adult progenies per family. By recording the leaf production of the progenies of the best palms in a population selected on their phenotypic values, the selected palms could be classified provisionally after 40 months, and the selected palms could then be immediately used for breeding purposes without waiting for yield data for at least 12 years.

Mathew and Ramadasan (1975) reported that there is significant positive correlation between the total chlorophyll content and annual yield of nuts in WCT palms. They also reported significantly more chlorophyll content in T x D and D x T hybrids than in WCT and dwarf palms.

Nampoothiri et al. (1975) observed significant genotypic correlations between production of spathes and female flower which were also positively correlated with yield, and height and age at first flowering, height and flowering leaf axil as well as age at first flowering and flowering leaf axil.

Sukumaran et al. (1981) studied 43 progenies from eight high yielding West Coast Tall palms and observed that average number of female flowers at 21-24 years, number of functional leaves at 19 years and "internodal distance at a fixed mark" at 19 years had the greatest direct effects on average yield of nuts at 21 to 24 years, by which age yield had stabilized.

Ramanathan (1984) studied the correlation coefficients of yield per plant and eight of its components for four dwarf and 26 tall cultivars and observed that a number of characters were significantly and positively correlated with yield ; stem height was most highly correlated (r = 0.6223).

A correlation study on length of leaf and yield of nuts by Nambiar and Govindan (1989) revealed that the high yielding palms had significantly more number of leaves than low yielding ones and that the longer the leaf, the higher was the yield. Under favourable conditions, the leaves of good yielders had a life span of 36 to 42 months. They reported that when every leaf produces an inflorescence in the axil, the palm is considered to be a regular bearer and as early as in 1930, the scientists at Pilicode observed that only 34 per cent of the WCT palms are regular bearers.

Vijayaraghavan and Ramachandran (1989) reported that the barren nut production is highest during the peak bearing period of South West monsoon, in both Tall and hybrids. They observed significant positive correlation between nut yield and barren nut production in both Tall and hybrids.

Balakrishnan et al. (1991b) reported high correlation between number of nuts produced per year with total nut production(r=0.904) and followed by total number of leaf production to total number of nut production (r=0.602).

Kalathiya and Sen (1991) reported that the nut yield was found to be significantly and positively correlated with number of spadices and duration of female phase whereas number of leaves produced and length of spadix exhibited significant positive correlation with number of spadices. It was suggested that number of spadices and duration of female phase should be considered as selection criteria for nut yield improvement in coconut variety dwarf green.

Liyanage (1991) reported that the genetic correlation between yield of nuts and copra per palm, is high and positive, between the flowering period and yield of copra is high and negative.

Mathew and Gopimony (1991a) reported that number of leaves in mother palms showed positive correlation with number of bunches whereas number of nuts per bunch showed negative correlation with most of the important nut and seedling characters.

Narayanankutty and Gopalakrishnan (1991) reported that there was significant positive correlation for total number of leaves retained by the palm (0.693**) and length of leaves (0.675**) with yield in coconut.

2.4 Fruit Component Analysis

While reviewing the evolution, dissemination and classification of coconut, Harries (1978) has proposed the use of fruit component analysis data as a rational approach to the classification of coconut varieties.

Rao and Pillai (1982) reported that measurements in terms of absolute values of palm height, leaf length and bunch production depend more on the age of the palm and need repeated recording, whereas the fruit components are more or less stable throughout the stabilized yield period. The kernel was given higher importance, whereby the selection pressure was always in the direction of bigger nuts (to realize higher kernel/copra)with lesser husk. The WCT which is the most commonly grown tall variety in the West Coast of India, showed higher husk proportion and is very near to the values of Niu kafa (the naturally evolved ones), the putative parental types described by Harries (1978).

2.4.1 Seednut selection

Mendiola (1926) pointed out that immediate improvement of coconut palm could be obtained through selection of seednuts.

Smith (1933) emphasized the need for seednut selection as well as study of nursery results in view of the fact that certain palms constantly yield nuts of low germination and poor growth characteristics.

Umali (1940) reported high germination percentage and better quality seedlings from thin husked nuts than from the nuts with husk thickness of 3.0 cm or above. Similarly nuts with less weight germinated late and produced poor quality seedlings compared to heavy nuts.

Kutty (1955) pointed out that only fully ripe nuts should be selected for seednuts and that the nuts from the top and the bottom of the bunches were less suitable for planting than those of the middle portion.

Marar and Varma (1958) concluded that the nuts of 11, 12, 13 and 14 month old bunches were equally suitable as seednuts.

Marar and Jayarajan (1960) recommended that for collection of seednuts, instead of lowering the bunches by means of ropes, the practice done for routine harvest can be followed without any disadvantage. However, they felt that the special practice may be adopted under conditions when the trees are considerably tall and the ground is hard.

Liyanage and Sakai (1961) reported that the heritability of nut weight (0.95) and copra (0.67) is high, stem girth (0.45), inflorescence production (0.47), female flower production (0.52), number of nuts per bunch (0.50) and yield of nuts (0.48) are intermediate. On the basis of these correlations, selection for high copra yield can be based on selection of palms bearing a high number of nuts and/or heavy nuts. The negative correlation between copra yield and length of period between planting and first flowering indicated that early flowering palms may be potentially high copra yielders.

Child (1964) reported that desirable high yielding palms include more with brown nuts than green nuts.

Manthriratna (1970b) emphasised the importance of seednut selection in generalized coconut improvement.

Silva and George (1970) suggested triphasic selection schedule for improvement of the coconut. Accordingly, the mother palm, seednuts and seedlings in the nursery, are to be exposed separately to selection.

Rognon and Lamothe (1976) pollinated 3 groups of Cameroon Red dwarf palms with pollen of the same variety, with pollen of W.African Tall and Tahiti tall respectively and observed that the copra content of the three crosses were 220g, 258g and 260g respectively. The shell weight of the D x T crosses was significantly heavier than that of the control, but as the shell is a maternal tissue this phenomenon needs to be accounted for.

Thomas (1978) studied the influence of seed size and the method of sowing on the germination and growth of the seedlings in the nursery, and found that the size influences earliness as well as increased percentage of germination, though not to the level of significance. Horizontal sowing of seednuts, preferably those that weigh 1000-1300 g each, is found to yield better results.

Louis and Ramachandran (1981) reported that the tall varieties, in general, recorded high oil content with a few exceptions. Oil content in the hybrids were medium and it was closer to the female parents. The dwarf varieties though possess leathery copra which slips away in the rotary making it difficult to extract the oil, possess comparatively good percentage of oil.

Santos et al. (1981) reported that in estimating copra yield, the weights of the fresh meat or split nut are more reliable basis than weights of whole or husked nuts. The existence of wide genetic variability in coconuts in the Philippines is confirmed and supports the hypothesis that copra recovery is influenced by some genetic factors.

Satyabalan and Vijayakumar (1981) reported that the mean copra outturn and oil content were highest in those obtained by selfing (unemasculated) followed by those from hybridisation with WCT (emasculated).

Wuidart and Lamothe (1981) concluded that sprouting was very much influenced by the stage of ripeness, with a peak at 12 months, gradually decreasing with age. The 11 and 10 month old groups required 10 and 42 days more respectively for reaching the 50 per cent sprouting level as compared to 12 month old nuts. The percentage of abnormal sprouts was very low for the 12 and 11 month old groups but became very high for 10 month old nuts and younger reaching almost 100 per cent for 7 and 8 month old groups. It was concluded that for these nuts the splashing water in the nut was no reliable criterion as regards the selection of ripe nuts, because even 10 and 9 months old nuts may have this character. The colour of the epidermis is a much more reliable indication of ripeness. In practice, it is recommended that only bunches bearing at least one healthy nut with a brown epidermis should be collected. Where the delay between collection and planting is expected to exceed one month, bunches with one or 2 nuts beginning to turn brown should be chosen.

Davis and Gosh (1982) reported that the female flowers getting fertilized during the dry months of July are 4-5 months old when the palm receives heavy rains which has the beneficial effect on the fast enlarging young fruits and this contributes to larger size of fruit that yields more copra per nut.

Meunier et al. (1982) reported that except for water and copra, one year's observation was enough to distinguish palms and lines planted in the same trial. More absolute values could only be obtained after 5-6 years sampling of 4 nuts every 2 months, because of seasonal and annual fluctuations.

Rao and Pillai (1982) reported that in coconut the kernel was given higher commercial importance, whereby the selection pressure was always in the direction of bigger nuts with lesser husk. They opined that the UCT showed higher husk proportion and resembles Niu kafa.

Shylaraj (1982) reported that in 'Komadan' it is desirable to have fairly large number of medium sized, round or near round nuts in the bunches and discard all malformed and defective ones before sowing in the nursery.

Bavappa and Sukumaran (1983) indicated the necessity for excercising selection pressure towards weight of copra per nut and oil per cent in addition to number of nuts.

Rajamony et al. (1983) conducted studies on the early performance of the hybrids with WCT as check variety and found that all hybrids were superior to WCT in respect of all characters studied. Maximum outturn of copra per palm per annum was also recorded by two hybrids.

Ramanathan and Louis (1983) reported that East Coast Tall x Malayasian Dwarf green hybrids had big nuts which gave the highest copra and oil yield. East Coast Tall x Malayasian Dwarf yellow was better than its reciprocal in nut and copra yield.

Satyabalan (1983) concluded that on the West Coast, the period January to April is the best for collection of seednuts. January nuts are to be preferred to May nuts for seednut purposes.

Meunier et al. (1984) reported that heritability estimates were higher for copra yield per nut and oil yield per nut and were fairly high for number of nuts per tree in crosses involving tall x tall and dwarf x tall.

Lamothe and Benard (1985) reported that the annual yields of Hybrid PB-111 are 100-150 nuts/tree with 200-240g of copra/nut and an oil content of 68 per cent (on dry matter basis).

Liyanage and Abeywardena (1985) reported preference for big and heavy nuts in seednut selection.

Satyabalan and Rajagopal (1985) reported that three out of 53 high yielding palms were stable yielders, giving an annual copra outturn of 15 kg per palm.

Jayalekshmy _et al_. (1986) reported that the volume of water in the nuts increased by nearly 77 per cent between the 6^{th} and 7^{th} months, although it started declining subsequently which could be due to the absorption of water by the developing endosperm as well as minor evaporation losses.

Nallathambi _et al_. (1986) evaluated six hybrids and the 7 parental genotypes for the oil content of their copra and observed that the highest heterosis over the mean and better parental values for this trait were in ECT x Gangabondam and ECT x Kanyakumari Dwarf yellow (13.4 and 12.4 per cent respectively, for both hybrids), ECT being the better parent.

Foale (1987) reported that based on a survey of coconut improvement work in various islands, several types with potential breeding value were identified and a wide spread of nut types were found, ranging in diameter from 158mm in Niu vai from Samoa to 90mm or less.

Ghose and Debnath (1987) opined that the morphological characters of seednut were found to be related with the quality of planting material.

Bourdeix (1988) reported that copra per nut is a very heritable character while number of nuts and copra per tree present significantly low heritability.

Ramanathan and Nallathambi (1988) reported that the fruit components viz. whole nut weight, dehusked nut weight, kernel weight and copra weight were not significant statistically. The hybrid ECT x DG gave the highest copra yield per annum as compared to the other hybrid ECT x CDO and ECT cultivar.

Nambiar and Govindan (1989) studied the influence of season on the size of nuts and reported that nuts harvested during April/May were the biggest and those harvested during December/January the smallest. The nuts harvested in the month of October were the smallest in volume. In copra recovery, the nuts harvested in the hot summer (March-April) were superior to those of the other months. They yielded more copra/nut. The nuts harvested in the cold winter months of December and January yielded more oil. They also reported that seednuts of both 11 and 12 month age groups are suitable for nursery purposes. Another study has revealed that the best time for the selection of seednuts was February to May which coincided with the summer season in Kerala. They also observed that spherical nuts germinated earlier.

Ramanathan (1989a) reported that the hybrids produced utilising the traditionally grown East Coast Tall as female parent, have exhibited different degrees of heterosis for the characters studied viz. nut and copra yield, nut components and oil content. ECT x MDG hybrids were found to express the highest vigour exceeding the values of greater parent and also other hybrid in terms of nut and copra yield, nut components and oil content and was released as VHC-1.

Chikkasubbanna et al. (1990) reported that the weight of nuts increased steadily from the sixth month onwards upto nine months and it tapered off as the last stage was reached. Increase in nut weight is due to an increase in size particularly the width. They also observed that there was a doubling of both the kernel as well as shell weight between the eighth and nineth months.

Paul (1990) reported that the total value of copra is dependent on the drying of the nuts and the quality of oil is dependent on the quality of copra. He also stated that quality of dehydrated or hot air dried copra is better than sun dried copra because greater rapidity of the process gives lesser time for the occurrence of enzymic or other changes likely to injure the fruit. He further suggested that good quality copra is obtained by drying the nuts at an average air temperature of 60°C, above which the copra showed a tendency to char. For maximum shelf life the moisture content of the copra should not exceed 6 per cent (from 50-55 per cent of wet meat).

Bourdeix et al. (1991a) stated that yield expressed as copra per palm can be broken down into three multiplicative factors: number of bunches, number of nuts per bunch and copra per nut. Copra per nut is usually the most heritable character and number of nuts per bunch is the most variable character.

Liyanage (1991) reported that the heritability values were high for copra per nut and copra per palm, intermediate for number of nuts and low for the flowering period.

Mathew and Gopimony (1991a) noticed extremely high heritability estimate for weight of unhusked nut, husked nut, meat and diameter of eye wheras thickness of meat registered low heritability value.

Taffin et al. (1991) reported that the dwarf hybrids proved to be greatly superior to local WAT coconuts in terms of precocity, number of nuts per hectare and copra per nut. Estimate of copra = weight of whole dehusked nut x 0.29.

2.4.2 Correlation studies on seednut characters

Silva and George (1970) showed a correlation between axis diameter and seedling vigour.

Correlation studies of 513 WCT palms were reported to have shown a high positive linear correlation between yield of nuts and total outturn of copra as well as copra content per nut and total outturn of copra (Anonymous, 1975).

Satyabalan (1982) observed that in WCT the mean yield of nuts was significantly and positively correlated with both annual outturn of copra and oil, whereas with mean copra content per nut it was negative and significant. The oil percentage in copra was not significantly related to yield of nuts. Studies on the relationship between yield of nuts, copra content per nut, total yield of copra and yield of oil per palm in WCT showed that the mean copra content per nut although negatively correlated with yield, did not affect the annual outturn of copra per palm, the threshold value being 162.6 nuts.

Satyabalan (1984c) observed a high positive linear correlation between yield of nuts and total outturn of copra as well as copra content per nut and total outturn of copra in WCT palms.

Satyabalan and Mathew (1984) reported significant correlation between weight of fruit (unhusked nut) and weight of husked nut, weight of fruit and weight of husk, weight of husked nut and wet weight of kernel, weight of husked nut and wet weight of shell, weight of husked nut and weight of copra, wet weight of kernel and weight of copra, weight of shell and weight of copra in the nuts of WCT harvested during different months of the year irrespective of the seasonal effects on these characters. Slight differences in the magnitude of the association noticed in the different months can be attributed to the effect of season prevailing during development.

Pillai et al. (1984) reported that the girth of seedlings and copra outturn were found to be correlated with the yield in dwarf selfed, and copra outturn was correlated with the yield of nuts in dwarf emasculated.

Balakrishnan and Vijayakumar (1988) reported the four nut characters viz., equatorial diameter of nut, weight of unhusked nut, weight of husked nut and weight of opened nut to be positively correlated with copra content of the nut. There was no correlation between the weight of shell and copra content in the cultivars studied. But the weight of opened nut and copra content were highly correlated than any other characters with a correlation coefficient of 0.9447. Equatorial diameter of the nut is more related with copra content than polar diameter of nut.

Valsala and Kannan (1990) observed positive significant correlation of polar circumference of seednut with girth of seedling (0.393) and also with equatorial circumference (0.472). Similarly the weight and volume of nut showed positive significant correlation with seedling girth. They also noticed that the correlation coefficient between nut characters and seedling characters like height and total leaf production were not significant. They concluded that bigger nuts in terms of volume and weight will give rise to vigorous seedlings and that for getting quality seedlings seednut selection should be practised.

Louis and Chopra (1991b) reported that among the five characters significantly correlating with copra weight, kernel weight, length of the petiole and thickness of shell had positive direct effects. Negative direct effects on copra weight were observed with the pre-flowering period and thickness of the kernel. Highest direct and positive effects on copra were observed by the kernel weight per nut, followed by leaflets and number of leaves produced in an year. The thickness of the shell had the least direct positive effect on copra.

2.5 Seedling selection

Selection of early germinating and vigorous seedlings in the nursery for planting in the field and discarding of later germinators and less vigorous seedlings has been practised for a long time, based to a large extent on intuition than on yield data of palms selected on this basis.

Liyanage (1953) suggested that careful standardised selection of seedlings is all the more effective in ensuring better later performance of seedlings. He found that selection at this stage alone could effect an increase in nut yield to a percentage of about 10. In Sri Lanka, a comparative study of the yield data of selected and unselected seedlings over a period of 19 years have shown that an additional 12 per cent increase in yield can be attained for the selected genotype.

Ninan and Pankajakshan (1961) reported that it is possible to isolate high yielders on the basis of seedling performance. So a switch over from mass selection to progeny row breeding (acknowledged to Dwyer, 1938), will be necessary to identify high yielders of outstanding breeding merit for use in propagation as well as breeding works.

2.5.1 Germination

Jack and Sands (1929) found that earlier germination of seednuts in coconut was associated with early bearing and consequent enhancement of production interms of nut yield. Hence early germination should be given the consideration it deserves while formulating the criteria for selection of seedlings.

Maceda (1933) reported that round nuts germinated earlier and produced more vigorous seedlings than oblong nut of the same volume.

Patel (1938) reported that there was difference in total germination between nuts from the top or bottom and from the middle of the bunch.

Umali (1940) observed that early germination and comparatively better nursery performance of seedlings were evident when seednuts were collected from trees with a higher setting percentage of 35 or more, coupled with a higher number of female flowers bearing rachillae (50.5 or more).

In selecting seed parents, it is advised to select palms giving nuts which sprout early (Anonymous, 1953).

Davis and Anandan (1957) opined that a nut may be considered to have germinated when the embryo broke the lid of the soft eye and this took place usually six weeks after the nut was sown.

Early sprouting along with early flowering and high initial yield are reliable early characters of a high yielding adult palm (Liyanage and Abeywardena, 1957).

Menon and Pandalai (1958) reported that the higher number of ungerminated seednuts might be due to the damage of the embryo caused by insect pest or fungus or may be due to the absence of embryo in some of the seednuts.

After reviewing the works of a number of researchers, Menon and Pandalai (1958) reported that the mean number of days for germination for Tall, Tall x Dwarf and Dwarf were 98.1, 70.2 and 55.3 days respectively.

Liyanage and Sakai (1961) found that it is advantageous to select seednuts for early sprouting in that it brings about a higher nut production, apart from early flowering.

Satyabalan *et al*. (1964) noticed that Tall x Gangabondam coconut hybrids germinated significantly earlier when compared to Tall x Dwarf and Tall x Tall.

Whitehead (1965) reported that the speed of germination was influenced by varietal characteristics. He observed that 'Malayan Dwarf' and 'San Blas' seednuts germinated rapidly and took only 30 to 140 days for 80 per cent germination whereas the speed of germination was very low in 'Jamaica Tall'which took 60 to 220 days.

Charles (1968) observed that seedlings derived from seednuts with a high copra content to have an advantage over seedlings sprouting from nuts with a low copra content. Therefore, other criteria which indicate a high yielding potential of the future mature palm in its seedling stage will improve the nursery selection.

Foale (1968) studied the growth of young coconut palm and the role of the seed and photosynthesis on seedling growth upto 17 months. The contribution by the endosperm fell at four months after germination to a level that remained roughly constant upto 17 months. By four months, the haustorium had reached the full size, but thereafter, relative contribution from the endosperm via the haustorium gradually diminished until by 15 months, almost full dependence on photosynthesis was attained. By 17 months less than 10 per cent of the endosperm remained in the nut.

Satyabalan et al. (1968) reported that the performance of hybrids of Tall with Dwarf Green and Dwarf Orange revealed significant differences in mean number of days taken for germination viz. 95.9 and 75.0 respectively.

Silva and George (1970) studied the influence of nut age and size using fallen nuts and first and second bunches and reported that within the first two months, the rate of sprouting was strongly influenced by the two factors but between the second and third month there was a rapid increase in the sprouting rate of the two less mature categories (second and first bunch nuts), and the influence of maturity was less visible. They further reported that at the end of the sixth month in the nursery, the significant effect of maturity on sprouting appeared as a dominant factor, with the first bunch nuts showing superiority over the more mature fallen nuts and the less mature second bunch nuts. Medium sized nuts from the first bunch had the best overall germination rate (95 per cent). During 10^{th} to 16^{th}

weeks, 70 per cent of second bunch nuts also sprouted irrespective of size.

Srinivasa and Ramu (1971) observed that in coconut seedlings developed from nuts that germinated within a period of 4 months had more leaves than those germinated later. The splitting of leaves into leaflets also was noticed to occur earlier in these seedlings. Such seedlings should be selected for planting so as to resolve a superior late stage performance.

Nampoothiri et al. (1972) reported that the average number of days between harvest and germination varied between 66 for Strait Settlement Apricot and 204 for WCT. With several cultivars germination was delayed by long storage.

Kenman (1973) noted that horizontally planted nuts with some husk removed from over the germpore germinated faster than untreated horizontally placed nuts.

Dutta (1974) observed that the upper end of the embryo develops into a small shoot. The speed with which this process happens varies with cultivars and this is one of the important factors to be taken into account in seedling selection.

Sento (1974, 76) reported that the optimum temperature and days to germination for coconut to be 30-35°C and 107 days respectively.

Sundaresan <u>et al</u>. (1974) reported that on the East Coast of India, preference is also given to planting seednuts between April and October for reasons of high percentage of sprouting and quality of seedlings.

Purseglove (1975) reported that the coconut seed has no dormancy and growth of the embryo and seedling is continuous. Germination may begin while the fruits are still attached to the palm, as can happen in 'Malayan Dwarf' and 'San Blas' when left unharvested.

Nelliat <u>et al</u>. (1976) found that nuts sown in June to September germinated earlier than those harvested in the warmer months. Nuts harvested during April-July and sown during June-September germinated earlier (average time 125 days after sowing). They also reported that nuts harvested from August to December and sown in October to February required a longer time (about 190 days) for germination. The results indicate that though the nuts germinate satisfactorily irrespective of the month of harvest, nuts harvested in April-July and sown in June-September germinate early.

Based on germination percentage of Dwarf x Tall hybrid seeds, and recovery of hybrids in open, self and cross pollination, dwarf parents could be selected for breeding programmes (Ninan, 1978).

Wuidart (1979) identified the criteria for selection of seedlings in earlier germination and differentiation of the sprout and recommended that individuals characterised by abnormality of any sort should be rejected summarily.

Harries (1982) used rate of germination as a criterion in the NKNVI method for comparing and contrasting cultivars and varieties of coconut.

Satyabalan (1983) conducted studies on the germination trend of WCT seednuts harvested during the different months and observed that there is not much difference in the germination rate between June and July sowings. Further, he advised to sow the seednuts of different harvests separately and record the germination date of each nut till December, in June and July sowings since more than 90 per cent of the seednuts would have germinated by December. He also found that nuts harvested during March had the highest germination, viz., 95.8 and 96.2 per cent for June and July sowing respectively. Germination declined to 73.9 and 52.2 per cent respectively for nuts harvested in May.

Satyabalan (1984a) reported that there is a set back in the growth of the seedlings in the nursery at the 5th month from the time of germination which is due to the complete utilisation of the endosperm by the seedling and a gradual change over to full dependence on photosynthesis for nutrition.

Satyabalan (1984d) stated that late germinated seedlings are inferior to early germinated ones and this is one of the points to be taken into consideration in selection of good seedlings.

Satyabalan (1985) conducted studies on the growth and yield performances of WCT seedlings germinated during different months and reported that there was very little difference in the rate of leaf production from the time of germination in the nursery in the seedlings germinated during August to October. He also found that the total number of leaves produced from the time of germination was more in October germinated seedlings than in the other groups. He also opined that the time of germination had no influence on the height of the seedlings, attained during the period of 26 years after transplanting. Further, he concluded that if the seedlings are measured for their growth characters from the time of germination to a particular time period, there may not be much difference between them, whether they germinate early or late and their mean yield difference may not be significant and hence early germination cannot be considered as an important criterion for selection of seedlings.

Anilkumar and Pillai (1989) observed significant difference in germination percentage between treatments after three, four and eight months of sowing. Germination percentage of Komadan seednuts was found to be significantly higher than that of WCT seednuts after third and fourth month of sowing. Though significant difference was not observed between WCT and Komadan seednuts after fifth and sixth months of sowing, Komadan seednuts after fifth month and WCT seednuts after sixth month recorded higher values. The germination percentage of WCT seednuts was found to be significantly higher than that of Komadan seednuts after eight months of sowing. This was found to be the case with total germination percentage as well. They also observed wide range of variations on the rate and germination percentage of WCT and Komadan seed coconuts under identical field conditions and reported that it might be due to cultivar characteristics. They further reported that there was significant difference on the number of ungerminated seednuts and that Komadan cultivars registered maximum number of ungerminated seednuts.

Satyabalan (1990) reported that earlier harvested seednuts germinated early whereas later harvested nuts germinated late and hence stated that it is difficult to apply the early germination criterion in the selection of seedlings of the Tall variety.

2.5.2 Correlation studies on germination of seednuts

Liyanage (1955) noticed highly significant positive correlation of 0.437 between sprouting of seednuts and flowering of palms and a negative correlation of 0.424 between sprouting and yield thereby showing that seednuts sprouted early give rise to palms that flower in a short period and are more productive than those sprouted later.

Liyanage (1966) observed that there was positive correlation between periods taken for sprouting of seednuts and flowering of the palms and a negative correlation between sprouting and yield. He also opined that if only the first yields are compared, the early sprouting palms have the advantage of maturing and reaching their full yield later. He further pointed out that there is no guarantee for later yields of such palms to be higher than those of slow germinators.

Nampoothiri et al.(1975) observed that the time taken for germination and number of leaves are negatively correlated. They suggested that apart from the rate of leaf production, this could be due to the increased duration of the time between germination and transplanting in the case of early germinating nuts.

Louis and Annappan (1985) studied the correlation between the various nut characteristics with the seedling characters and observed that irrespective of the size and shape, nuts of low or medium weight had the highest germination (99-100 per cent), which overall ranged from 90 to 100 per cent.

Valsala and Kannan(1990) reported that number of days taken for germination was negatively correlated with seedling character. It showed negative correlation coefficient of 0.429 with collar girth. They opined that early germinated nuts produced seedlings having more collar girth and faster leaf production.

2.5.3 Seedling growth analysis

The study of seedling growth analysis is usually undertaken by recording and analysing the observations on plant height, girth at collar, number of leaves, total leaf area and age at leaf splitting.

Fremond and Brunin(1966) found that rapid early growth of seedlings was associated with earliness in flowering.

Liyanage(1966) reported that seedlings selected in the nursery gave significantly higher yields than unselected seedlings during the first fifteen years. He further reported that the seedlings had been selected on the following criteria (a) early sprouting (b) vigour (c) resistance to pests and diseases.

Nelliat <u>et al</u>.(1976) reported that the seedlings raised from nuts sown in June and August were significantly superior to others in growth characters.

Progeny studies conducted on 20 progenies of each of 15 WCT palms from Kuttiadi seednut centre at Nileshwar have indicated that only 2 families out of 15 have recorded high yields (Anonymous, 1977).

Kannan and Nambiar (1979) studied the influence of mother palm and seedling selection on the performance of progenies and observed that for ensuring better establishment, early flowering and higher yield, poorer seedlings should be identified and rejected even if they have a scientifically identified superior mother palm source.

Mathai (1979) reported that observations on girth at collar, number of leaves produced, height and time of flowering indicated that tall x dwarf and tall x Gangabondam which are crosses between widely different varieties exhibited hybrid vigour beyond the seedling stage. Among the 2 hybrids, the amount of hybrid vigour exhibited by T x D was on par with tall x Gangabondam in respect of girth at collar, number of leaves and height.

Wuidart (1979) identified the criteria for selection of seedlings in earlier germination and differentiation of the sprout and recommended that individuals characterised by abnormality of any sort should be rejected summarily.

Satyabalan (1984b) concluded that the rapid seedling growth in the first five months was attributed to utilization of the endosperm and a subsequent decrease in rapid growth to the seedlings full dependence on photosynthesis. The selection of seedlings for transplanting in the fifth month after emergence was recommended.

Satyabalan (1984d) reported that rigorous selection of seedlings is made in the nursery on the basis of growth characters, collar girth and leaf production for planting in the field.

Ramanathan (1987) reported that the characters in coconut seedlings are influenced by the genetic make-up of parents involved in the hybrids and the relationship between different seedling characters differ accordingly.

Anilkumar and Pillai (1990) noticed while comparing the effect of sowing dehusked and husked nuts that there was no significant influence of presowing preparation on seedling charaters such as height, number of leaves and girth at collar. They also reported that dehusking of seednuts did not adversely affect germination and had no deleterious effect on seedling vigour and production of quality seedlings.

Kasturibai and Ramadasan (1990) opined that vigour of seedlings based on girth at collar, height and number of leaves showed that vigour is expressed at the sixth month growth itself after sowing.

Satyabalan (1990) reported that there is only slight variation if the growth characters are measured from the time of germination to a particular period. These variations may be due to the climatic factors prevailing during the development of the seedling. He also observed that irrespective of the month of germination, the growth of the seedling during the first five months from the time of germination is more than that of the second five months because in the beginning the seedling utilises the endosperm till the fifth or sixth month and afterwards it is fully dependent on photosynthesis for nutrition, resulting in a setback in growth.

Louis and Chopra (1991a) reported the importance of dominant gene (sca) effects for early germination and additive gene effects (gca) for seedling girth, height and breadth of laminate leaf. Additive and dominant gene actions were true for increased number of leaves in the seedling.

Rethinakumar et al.(1991) reported that the characters which contributed to high index score for selection were duration taken for germination, length and width of embryonic leaves, along with collar girth and height of seedlings at fourth month of growth and that it is possible to identify the superior planting material during their fourth month of growth itself based on the use of selection index.

Sreerangasamy and Sridharan (1991) suggested that the three parameters for minimum standards for seedling vigour are 6cm girth at base, six number of well developed leaves and atleast one fully split leaf at 10 months after sowing. These parameters were highly and positively correlated with one another.

2.5.3.1 Height of seedling

As in any other crop, plant height is an important phenotypic manifestation of growth in coconut seedlings also.

Liyanage and Abeywardena (1957) elucidated that mother palm selection could be made more efficient by selecting trees which would produce a higher percentage of tall vigorous seedlings.

Menon and Pandalai (1958) reported the average height of seedlings of Tall, Tall x Dwarf and Dwarf origin to be 83.56, 103.63 and 87.54 cm respectively after reviewing the works of Rao and Koyamu conducted in 1952.

Louis (1981) studied the phenotypic and genotypic variability in coconut in a collection of 25 varieties and two hybrids and observed a high genotypic coefficient of variation for the height of seedlings in the third year indicating that this character is less susceptible to random environment.

In a study conducted to compare seedling progeny analysis of Komadan and WCT, Gopimony (1982) observed that the seedlings of Komadan exhibited superior seedling vigour in terms of height, collar girth, number of total leaves, mean number of split leaves and germination percentage compared to WCT.

Shylaraj (1982) concluded that tall seedlings with a good collar girth measurement that bear relatively larger number of split leaves are to be selected preferentially in 'Komadan'.

Louis and Annapan (1985) reported that the seedling height at nine months was greatest (92 cm) in seedlings from normal round uniform nuts weighing 115.17 g. In 12 months old seedlings the height was greatest (147 cm) from medium uniform round nuts weighing 1045.36 g.

2.5.3.2. Number of leaves

The works of Patel (1938) and Rao and Koyamu (1955) as quoted by Menon and Pandalai (1958) stated that the number of functional leaves of seedlings to be 3.8, 5.0 and 5.0 for Tall, Tall x Dwarf and Dwarf seedlings respectively.

Charles (1959) stated that seedling selection is based on the vigour of seedlings as judged at the four-leaf-stage by spread and colour of leaves and other measurable characters like collar girth, rapidity of growth and overall sturdiness of seedlings.

Marar (1960) proposed the establishment of elite seed gardens for producing quality coconut seedlings from open pollinated nuts collected from desirably identified mother palms and to make a rigorous selection among the seedlings where one of the important criteria of selection was increased number of leaves.

Satyabalan et al. (1964) based on a comparative study of Tall x Dwarf, Tall x Gangabondam and Tall x Tall hybrids reported that these hybrids showed close resemblence in leaf production in nursery.

Data collected from open pollinated progeny of Tall x Dwarf hybrids indicated their superiority in leaf production when compared to West Coast Tall (Anonymous, 1965).

Foale (1968) noted that rate of leaf production was constant with time after tracking the growth of young coconut palms upto 17 months of age.

Satyabalan et al. (1968) observed that Tall x Dwarf Green and Tall x Dwarf Orange produced 6.70 and 7.00 leaves in a year respectively while comparing the different dwarf parents for use in Tall x Dwarf hybrid production.

Srinivasa and Ramu (1971) observed that in coconut seedlings developed from nuts that germinated within a period of four months had more leaves than those germinated later. Such seedlings should be selected for planting so as to resolve a superior late stage performance.

Mathai(1979) observed that Tall x Dwarf and Tall x Gangabondam exhibited same degree of hybrid vigour during and even after seedling stage in relation to number of leaves produced.

Ramadasan et al. (1980) reported that leaf number could be used as a component in computing seedling vigour in terms of shoot dry weight, based on linear multiple regression equation incorporating other seedling characters like height, girth at collar and leaf area.

Louis (1981) reported that moderately high genetic advance was combined with moderately high heritability for the length of leaf and number of leaves in the crown indicating the predominance of additive genes, which was considered a desirable feature for selection.

In a study on the seedling vigour in relation to the size and shape of seednut in Tall variety, Louis and Annappan (1985) observed that the highest percentage of nine month-old seedlings with a sixth leaf occurred in groups I (small nuts with tapering end weighing 654.18g) and VI.

Satyabalan (1985) noticed in studies conducted on the growth and yield performance of WCT seedlings germinated during different months that (1) there was very little difference in the rate of leaf production from the time of germination in the nursery in the seedlings germinated during August to October (2) there was not much difference in the rate of leaf production per year during the period of ten years after transplanting in the field in the seedlings germinated during August and September. But October germinated seedlings recorded a high rate of leaf production only during fifth to seventh year after transplanting and afterwards the rate of leaf production was similar to those in the other two groups. The total number of leaves produced from the time of germination was more in October germinated seedlings than in the other two groups.

2.5.3.3 Girth at collar

After reviewing a number of reports, Menon and Pandalai (1958) observed that girth at collar of Tall, Tall x Dwarf and Dwarf seedlings are 9.14, 10.67 and 9.65 cm respectively. They reported that girth at collar is the most important selection character.

The seedlings of Tall x Gangabondam recorded superior collar girth, though not significant when compared to Tall x Dwarf hybrids and both were found to be distinctly superior to Tall x Tall hybrids in this character (Satyabalan et al., 1964).

Satyabalan et al. (1968) observed that the Tall x Dwarf Orange hybrids were found to be significantly superior in collar girth to Tall x Dwarf Green hybrids with means 12.12 and 10.96 cm respectively.

Silva and George (1970) reported that seedlings of fallen over ripe nuts with large size (20 cm short axis) produced seedlings with maximum collar girth.

Satyabalan and Mathew (1977) reported that it is possible to identify palms of superior genetic value based on collar girth and leaf production of progenies recorded from the fifth month after germination.

Mathai (1979) observed that Tall x Dwarf and Tall x Gangabondam hybrids exhibited similar degrees of hybrid vigour in collar girth even after nursery stage.

Louis (1981) reported that inspite of high heritability for girth at collar, the genetic advance varied but was considerably high and it was concluded that selection was possible for such characters.

Louis and Annappan (1985) observed that the mean collar girth was greatest (10.7 cm) in seedlings from egg shaped nuts weighing 960 g in a study on seedling vigour in relation to the size and shape of seednut in Tall variety of coconut palm.

Ramadasan et al. (1985) reported that since the girth at collar is mostly contributing to seedling vigour, the suitability of choosing girth at collar alone as the seedling selection character is worth exploring.

2.5.3.4 Total leaf area

Leaf area and dry matter production are two plant characters that determine the total biological productivity.

In cultivated perennial tree crops, such growth analytical studies are rare. Rees (1963) was the first to attempt growth analysis in oil palm (Elaeis guineensis Jacq.) followed by a few such reports in coconut (Rees and Tinker, 1963 ; Hardon et al., 1969 ; Corley et al., 1976). In the adult coconut palm, Pillai and Davis (1963) made the first attempt in determining the dry matter yield after destructive analysis of one adult WCT coconut.

Foale (1968) observed that leaf area increased almost exponentially with increasing age while analysing the growth of the young coconut palm up to 17 months of age.

Ramadasan et al. (1980) observed that in addition to other seedling characters mentioned elsewhere, leaf area should be an important criterion in selecting coconut seedlings. The authors calculated the leaf area using a regression equation.

$Y = a + bX$, where Y represented leaf area, $a = 27.3861$, $b = 0.6139$ and X = product of length and width of leaf. This study also revealed that the more contributing factor for the vigour of seedlings as indicated by shoot dry weight are leaf area and girth at collar.

Mathes *et al.* (1989) proposed a rapid non-destructive and accurate method for determining the leaf area of one, two and three year old coconut seedlings using three linear regression models.

$y = 5.9647 + 0.6314\,x$, $y = 3.9325 + 0.7044\,x$ and $y = 8.4507 + 0.6798\,x$ with reliabilities of 94.5 per cent, 98.3 per cent and 97.8 per cent respectively, where x is the product of the length and breadth at the broadest position of the leaflet and y is the area of the leaflet. In order to study the relative performance of seedlings, a common model $y = 2.2138 + 0.7192\,x$ (r^2 = 98.6 per cent) which can be considered to be representative, could be used irrespective of the age of the seedling, if the third leaf is used. They were of the opinion that the vigour of a coconut seedling is indicated by the length and number of fronds, number of leaflets etc. These are in effect related to the total leaf area of the palm which would be related to the degree of photosynthesis.

2.5.3.5 Age at leaf splitting

Age at leaf splitting is another sign of vigour in the seedlings. Menon and Pandalai (1958) concluded that early splitting of leaves was a sign of precocity since the seedlings which commenced to produce leaves which tend to split into leaflets when the seedlings had eight to ten leaves showed early flowering.

Srinivasa and Ramu (1971) reported that nuts which germinated early (within four months) produced seedlings where splitting of leaves into leaflets occurred earlier.

2.5.4 Miscellaneous characters used in seedling selection

2.5.4.1 Petiole colour

Petiole, inflorescence and fruit colours correspond closely and colour differences between forms are normally distinguished at the nursery stage. The shade of the colour depends on the homozygosity of the palm for the colour.

Genetic studies showed that a seedling with a bronze rachis was a hybrid resulting from a cross involving Malayan dwarf, which had a green rachis, as female parent (Anonymous, 1966).

Whitehead et al. (1966) observed that dwarf x tall hybrids and reciprocal crosses, produced by controlled pollination, had petiole colours characterstic of tall parent. The tall colour is evidently dominant to that of the yellow and red colours of the Malayan Dwarf.

Rognon (1972) suggested the use of petiole colour in selection of hybrids at germination. The Nain x Nain(dwarf) selfs could be thus isolated from Nain x Grand (Tall) hybrids on the basis of petiole colour.

Harries (1976) studied the transmission of colours in crossings wherein he observed that the crossing of a green parent with a red parent produced a green offspring and the bronze colour of both parents is dominant of all other colours, the yellow colour being recessive.

Lamothe snd Rognon (1977) observed that a yellow palm crossed with another yellow palm will never result in red, brown or orange progenies. The crossing of a green palm with a red or orange palm homozygous for this colour will always produce brown offsprings. The colours orange and brown used by Lamothe and Rognon were apparently called red and bronze respectively by Harries(1976).

2.5.4.2 Chlorophyll content

Ramadasan et al. (1985) observed high heritability for total chlorophyll content while studying the heritability of seedling vigour in coconut palm, and confirmed the association of high chlorophyll content with high vigour and productivity.

2.5.4.3 Shoot dry weight

A multiple linear regression equation based on height of seedlings, number of leaves, girth at collar and leaf area was worked out by Ramadasan et al. (1980) for estimating the dry weight of shoot. The equation was as follows.

$$Y = -112.4464 + 12.5885\ X_1 + 0.2295\ X_2 - 5.6338\ X_3 + 0.0143\ X_4$$

where Y represented shoot dry weight

X_1 - girth at collar, X_2 -height of seedling,

X_3 - number of leaves and X_4 - leaf area.

The author observed that shoot dry weight can be used as an index of vigour in seedling selection process in coconut improvement.

2.5.5 Correlation studies on seedling characters

Menon and Pandalai (1958) observed that girth at collar was more correlated with weight of seedling (an indication of vigour) than any other character studied.

Pankajakshan and George (1961) noticed positive correlations between girth at collar with both height and leaf number. About 60 per cent of the variation in girth is controlled by the combined influence of height and number of leaves.

Correlation studies between leaf area and length and width of leaves were undertaken in coconut seedlings by Marar and Pappachan (1964). They coined a method for estimating the leaf area ie., to multiply the product of length and width of leaf lamina by a coefficient of 0.878.

Liyanage (1967) noticed a significant positive correlation between leaf production and the mean yields of the adult progenies per family.

Mathew and Ramadasan (1975) reported that there was significant positive correlation between total chlorophyll content and annual yield of nuts in WCT palms. They also reported significantly more chlorophyll content in T x D and D x T hybrids than in WCT and dwarf palms.

Nampoothiri et al. (1975) studied phenotypic and genotypic correlations of certain characters with yield in coconut and found that girth at collar was the only seedling character which showed significant phenotypic correlation. This study therefore formed the basis of the recommendation that seedling selection should be practiced in favour of number of leaves and girth at collar.

Ramadasan et al. (1980) reported that although seedling height and number of leaves per seedling were highly correlated with shoot dry weight, their direct effects were negligible. They found girth at collar had a high direct effect on the shoot dry weight of seedling (seedling vigour). They also reported that leaf area showed maximum direct effect and positive correlation with shoot dry weight.

Satyabalan (1984b) based on detailed studies of progenies had reported high and positive correlation of growth characters like collar girth and leaf production from the fifth month after germination with those of later months.

Ramanathan (1987) reported that there was significant positive correlation of seednut weight with seedling height and girth at collar in ECT x Ayiramkachi and ECT x Malaysian Dwarf Green hybrid while there was no such correlation in the case of ECT x Malaysian Dwarf yellow hybrid and in ECT cultivar.

Valsala and Kannan (1990) while studying the influence of seednut characters on seedling vigour observed that the girth at collar showed high significant positive correlation with height and total number of leaves produced.

Mathew and Gopimony (1991a) reported that the overall seedling vigour index is positively and significantly correlated to important seednut characters. All the growth parameters of seedling showed significant positive correlation with recovery of quality seedlings in WCT.

2.6 Seedling progeny analysis

The breeding behaviour of an individual plant is learnt by growing its progeny. Selection of superior plants from a mixed population is usually made on the basis of appearance or phenotype. Progeny analysis provides an opportunity to evaluate the genotype of the selected plant (Poehlman and Borthakur, 1969).

Vilmorin (1856) as quoted by Hayes et al.(1955), developed the progeny test with reference to sugar beets and the method developed is known as Vilmorin's isolation principle. This principle briefs that, the only sure means of knowing the value of an individual plant selection is to grow and examine its progeny.

It has been quoted by Hayes et al.(1955) that Johanssen (1903, 1909) placed individual plant method of selection and progeny testing on a firm scientific base through developing the pureline theory.

In coconut improvement, Harland (1957) was the first person to stress the need for progeny analysis. Later complete (adult) progeny test was used in coconut improvement by Ninan and Pankajakshan (1961), Liyanage (1967, 72), Abraham and Ninan (1968), Tammes and Whitehead (1969) and Kannan and Nambiar (1979).

Ninan and Pankajakshan (1961) suggested that if sufficiently large numbers of mother palms are tested, trees which combine high yield, low standard deviation value and superior progeny characters could be detected, though such of them are very few. Since it is seen that trees giving superior seedlings in one year continue to do so in the next year, it becomes evident that in detection of such trees, data of progeny for one year may be sufficient.

Nambiar and Nambiar (1970) reported the relative advantages of seedling progeny analysis over a complete (adult) progeny testing. They concluded that, in coconut which has a long generation interval, by relating seedling growth characters with adult palm performance, inferior genotypes can be eliminated at an early stage.

Mathew (1983) found seedling progeny analysis to be useful in identifying superior mother palm in an attempt to evaluate the super mother palms of coconut.

2.7 Prepotency

Darwin (1859) was the first to use the word `prepotent' which he explained as follows : "when two species are crossed, one has sometimes a prepotent power of impressing its likeness on the hybrid, and so I believe it to be with varieties of plants. With animals, one variety certainly often has this prepotent power over another variety".

Harland (1957) opined that the good performance of all mother palms selected on a phenotypic base only was not the result of genotypic superiority. According to him, once female transmitters are identified, their pollen can also be used on phenotypically high yielding mother palms, thus making available a very large quantity of good planting material. He also suggested that the process of identifying male transmitters can be speeded by the used of dwarf palms as female parents. They are precocious and high yielding. He also recognized that a few palms had superior progenies resulting from open pollination. Such palms were called "prepotent". He suggested that it was possible to cross identified prepotent palm for the breeding of improved plant material. He also suggested that the good character of such prepotent palms could be fixed by selfing. Such prepotents have been identified at C.P.C.R.I., Kasaragod (Satyabalan *et al*., 1975).

Allard (1960) defined prepotency as the capacity of a parent to impress characteristics on its offspring, so that they resemble that parent and each other more closely than usual.

Liyanage (1961) stated that prepotency may be due to the high additive genetic value and/or the general combining ability of the palm since these two characters are known to segregate in other crops, it should be possible to fix prepotency by selfing and selections, depending on its basis.

Ninan and Pankajakshan (1961) opined that palms with genetic superiority are of two types, the first having a favourable combination of genes in the heterozygous condition or hybrid phase and the second, which are sufficiently possessed of dominant genes to ensure that their progenies are also high yielding. Those high yielders which continue to maintain sufficiently high progeny value irrespective of the type of pollinating male are inherently superior and may be regarded as having sufficient load of dominant yield factors to be called prepotent.

Based on the trials conducted in coconut, Liyanage (1967) suggested that seedling progeny analysis is effective in identifying prepotent palms.

Liyanage (1972) opined that prepotency could be due to the function of superior general combining ability as observed in field crops.

Nampoothiri et al. (1975) reported that seedling characters like collar girth and leaf production are genetically correlated with yield of adult palm and it may be possible to identify palms of superior genetic value (prepotent) even from the fifth month based on these two growth characters.

Satyabalan et al. (1975) indicated the possibilities of identifying prepotent palms based on progeny performance in the nursery.

Satyabalan and Mathew (1977) observed that seedlings raised from the nuts of prepotent palms were more vigorous than those of other palms irrespective of the month of harvest and germination. They observed that prepotent palms can be identified from the nursery studies itself on the basis of growth rate and seedling vigour as measured by girth at collar and leaf production. They also observed that correlation of these growth characters from the fifth to nineth months with those of tenth month indicated a high and positive correlation from fifth month onwards thereby showing that it might be possible to identify palms of superior genetic value from over fifth month for prepotency.

Welsh (1981) reported that general combining ability is manifested by additive genetic variance and this variation is credited to the additive action of quantitative genes.

Gopimony (1982) reported that since Komadan coconut type is considered to be of self pollinated nature, it is assumed that the prepotency carried by the mother palms will be transmitted to their progenies.

Satyabalan (1982b) reported that the main basis of selection of mother palms is their yield and by this type of selection it is possible that palms which are genetically superior but located in an unfavourable environment may get eliminated and those with poor inherent capacity but high yielding due to favourable environment may get selected. Hence to improve the overall yield in coconut plantations, open pollinated progenies of genetically superior high yielding mother palms (prepotent) have to be planted.

Mathew et al. (1984) while evaluating the super mother palms of coconut reported that only one among the selected palms proved superior to the controls both as mother palm and in its capacity to transmit its trait to its seedling progeny.

Satyabalan and Rajagopal (1985) while studying the growth characters of the progenies reported that prepotency is not transmitted to all the open pollinated F_2 progenies of the prepotent palms identified earlier.

Ramanathan (1989b) reported that among the 10 mother palms studied, six were genetically superior with high degree of prepotency. Out of 127 palms in the progenies, 33 palms gave superior yield performance, the percentage of such superior palms being 26.

Nair et al. (1991) suggested that since it is possible to identify prepotent palms based on progeny performance, all the traditional cultivars must be screened for prepotency for use in breeding programs as well as in replanting and underplanting programs.

Nampoothiri (1991) suggested that once prepotent palm is identified large number of its progenies with predictable yield can be produced for further use in selection and hybridisation. The procedure adopted in identification of prepotents should involve selection of very high yielders (150 nuts/palm/year and above) coupled with yield attributes, stringent seedling selection, systematic progeny testing and simultaneous evaluation of their utility as pollen parent and the final selection.

2.8 Inbreeding

Ohler (1984) reported that although it was not proved that there was real autogamy in tall coconuts, the researchers stressed certain characteristics favouring it.

(a) No incompatibility phenomenon has ever been shown at the research station among the thousands of selfings carried out.

(b) Two successive inflorescences in the same palm are much closer to each other than they are to those of neighbouring palms.

(c) Ants (potential pollinators) seldom go from palm to palm but often go from one inflorescence to the next on the same palm.

It was concluded that autogamy is therefore possible in tall coconuts and that it is likely that the autogamy rate is higher when ecological conditions are more favourable.

Harland (1957) stressed the fact that different varieties of coconut will respond to selfing in different ways and to a different extent. According to him, by mutation a large number of unfavourable recessive genes may have accumulated becoming apparent on selfing. The depression effect might be compensated for by a greater uniformity in yield and other desirable characters.

Haldane (1958) suggested that selfing should only be continued for two or three generations, the lines obtained could show interesting recessive characters. Inbreeding, although not directly through selfing, must have taken place in many isolated coconut populations on small islands having been derived from only one or very few nuts.

Menon and Pandalai (1958) reported that seedlings from selfed progenies were less vigorous than those form cross-pollinated and naturally pollinated seednuts. However, the performance of selfed seedlings depend on the genetic composition of the selfed parent.

Liyanage (1967) reported a quick method of identifying good genotypes by studying the inbreeding depression on endosperm and embryo weight of nuts. If either of these parameters are under genic control, one would expect differential behaviour between genotypes when selfed, depending on the nature of genes involved. If it is largely due to the prepotency exhibited by additive effects of genes, the inbreeding depression may not be significant or even negligible than when it is controlled by hybrid vigour expressed by dominance or epistasis. This makes it possible to isolate palms of high breeding value from phenotypically superior palms by selfing them and studying the depression on endosperm and embryo weight per nut relative to those of the open pollinated nuts from the same palm. This method takes only twelve months to test the breeding value of a palm, as against twelve years required by progeny testing.

Liyanage (1969) alternately self-pollinated or open-pollinated the inflorescences of selected high yielding palms and of palms taken at random. Generally, there was an inbreeding depression on all the characters studied; inbred palms carried fewer leaves and had taken a longer period for flowering than open-pollinated palms. But the intensity of depression varied between families.

According to Harries (1981), self-pollination in introgressed and Niu vai forms is encouraged under cultivation because it leads to uniformity. The highly self-pollinated dwarf coconut varieties are examples of this tendency.

Bourdeix (1988) reported that selfing induces inbreeding depression in tall ecotypes since it induces a drop in vigour, number of nuts and copra per nut. This phenomenon was accompanied by a reduction in chiasma frequency which corresponds to a reduction in recombination frequency. Inbreeding depression particularly affects copra per tree, number of nuts, number of bunches and flowering precocity. The fact that it spares copra per nut can be explained by the triploid nature of this tissue, the flow of genes brought by the pollen restores heterozygosity which limits inbreeding depression.

Nambiar and Govindan (1989) reported that coconut being a natural cross-pollinated crop is found to exhibit inbreeding depression and this phenomenon has been confirmed by repeated selfing of five elite palms at Pilicode from 1926 onwards.

Bourdeix *et al*. (1991a) stated that the selfs are difficult to obtain for several reasons : for certain parents, it is necessary to proceed with selfing for several years before a family of 100 progenies is obtained. In addition, selfs often produce low nut yields in talls which is due to inbreeding depression.

Nair and Balakrishnan (1991) reported that studies made on the first and second generation selfed progenies revealed that selfed progenies were inferior to their grand parents and sibs. Hybrid vigour was met with when crossing was done between the progenies of the same parent and it clearly indicated inbreeding depression in coconut by selfing.

Nair *et al*. (1991) opined that where inbreeding depression is apparent, introgression with other palms should be attempted to correct the weakness after which a second phase of selection of inbreeding may be attempted.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The experiment was conducted in the Department of Plant Breeding, College of Agriculture, Vellayani during the period from October 1988 to August 1990.

3.1 MATERIALS

The material consisted of the following five varieties/types of mother palms.(Fig.1-a to e.)

(i) First generation `Komadan' palms (KI) from the centre of origin.

(ii) Second generation `Komadan' palms (KII) growing in the Instructional Farm, College of Agriculture, Vellayani under Kerala Agricultural University.

(iii) Third generation `Komadan' palms (KIII) originated from the mother palms of item (ii) above growing within and outside the Vellayani campus.

(iv) West Coast Tall palms (WCT) of the same age and yield group as in item (ii) above growing in the Vellayani campus of Kerala Agricultural University.

(v) Known Natural Cross Dwarf mother palms (NCD $-F_1$ generation)growing at the Regional Agricultural Research Station, Pilicode.

Ten mother palms were selected from each variety/type during 1988 based on the typical identification characters of each variety/type as well as the mean nut yield per tree per year assessed for the previous three consecutive years. The top ranking ten trees showing the type characteristics (Menon and Pandalai 1960; Ohler, 1984) were selected for the study. The treatment number, location, district, age and annual nut yield of the selected palms are given below.

Table 1. Details of experimental material

(1) First generation Komadan palms

Sl. No.	Trea-ment No.	Location	District	Age	Annual nut yield
1.	K_1	Thottapuzhassery	Pathanamthitta	40	175
2.	K_2	-do-	-do-	45	197
3.	K_3	-do-	-do-	45	215
4.	K_4	-do-	-do-	65	185
5.	K_5	-do-	-do-	65	180

6.	K_6	-do-	-do-	65	220
7.	K_7	-do-	-do-	65	200
8.	K_8	-do-	-do-	60	205
9.	K_9	-do-	-do-	65	128
10.	K_{10}	-do-	-do-	65	200

(ii) Second generation Komadan palms

Sl. No.	Treament No.	Location	District	Age	Annual nut yield
1.	K_{11}	Vellayani	Trivandrum	32	148
2.	K_{12}	-do-	-do-	32	112
3.	K_{13}	-do-	-do-	32	85
4.	K_{14}	-do-	-do-	32	160
5.	K_{15}	-do-	-do-	32	140
6.	K_{16}	-do-	-do-	32	151
7.	K_{17}	-do-	-do-	32	145
8.	K_{18}	-do-	-do-	32	124
9.	K_{19}	-do-	-do-	32	140
10.	K_{20}	-do-	-do-	32	99

(iii) Third generation Komadan palms

Sl. No.	Treament No.	Location	District	Age	Annual nut yield
1.	K_{21}	Peroorkada	Trivandrum	15	180
2.	K_{22}	-do-	-do-	15	178
3.	K_{23}	Gowreesapattom	-do-	15	125
4.	K_{24}	Vellayani	-do-	15	130
5.	K_{25}	Nedumangad	-do-	13	160
6.	K_{26}	Vellayani	-do-	15	120
7.	K_{27}	-do-	-do-	15	105
8.	K_{28}	-do-	-do-	15	155
9.	K_{29}	-do-	-do-	15	140
10.	K_{30}	Nedumangad	-do-	13	210

(iv) West Coast Tall palms

Sl. No.	Treament No.	Location	District	Age	Annual nut yield
1.	W_1	Vellayani	Trivandrum	30	180
2.	W_2	-do-	-do-	30	118
3.	W_3	-do-	-do-	30	89
4.	W_4	-do-	-do-	30	130

5.	W_5	-do-	-do-	30	108
6.	W_6	-do-	-do-	30	120
7.	W_7	-do-	-do-	30	125
8.	W_8	-do-	-do-	30	115
9.	W_9	-do-	-do-	30	110
10.	W_{10}	-do-	-do-	30	132

(v) Natural Cross Dwarf palms

Sl. No.	Trea- ment No.	Location	District	Age	Annual nut yield
1.	N_1	Pilicode	Kasaragod	30	170
2.	N_2	-do-	-do-	30	118
3.	N_3	-do-	-do-	30	92
4.	N_4	-do-	-do-	30	95
5.	N_5	-do-	-do-	17	85
6.	N_6	-do-	-do-	30	100
7.	N_7	-do-	-do-	30	120
8.	N_8	-do-	-do-	30	115
9.	N_9	-do-	-do-	30	80
10.	N_{10}	-do-	-do-	12	103

Fig. 1 - a. First generation Komadan mother palm (KI)

Fig. 1-b. Second generation Komadan mother palm (KII)

Fig. 1-c. Third generation Komadan mother palm (KIII)

Figure 1-a

Figure 1-b

Figure 1-c

Fig. 1-d. West Coast Tall mother palm (WCT)

Fig. 1-e. Natural Cross Dwarf mother palm (NCD)

Figure 1-d

Figure 1-e

3.2 METHODS

3.2.1 Studies on mother palms

The following observations were recorded on all the ten mother palms in each of the five groups during the period from October 1988 to December 1988.

(i) Age of the palm

Age of the palm was recorded in years. Age was determined by counting the leaf scars on the trunk. Roughly 12-14 successive scars left on a tree correspond to a year of growth of the tree (Menon and Pandalai, 1958).

(ii) Number of leaves

Fully opened leaves on the crown were counted.

(iii) Number of bunches and spadices

Bunches were counted down from the youngest inflorescence with male or female flowers in anthesis to the oldest bunch in each tree.

(iv) Number of unopened spadices

All those spadices which were unopened but fully or partially emerged were counted.

(v) Number of female flowers per bunch

Female flowers on the youngest inflorescence with male or female flowers in anthesis were counted from three such inflorescence emerging within a year at random and the mean number of female flowers per bunch obtained.

(vi) Number of nuts per bunch

Nuts were counted on all bunches upto button stage of each mother palm and mean number of nuts per bunch obtained.

(vii) Number of nuts per palm per year

The total number of nuts in a palm was counted from the oldest bunch to the youngest bunch where the nuts were in button stage.

(viii) Pigmentation on leaf stalk and nut

Pigmentation was scored as per standards fixed in the "Nickerson Color Fan (1957)".

(ix) Pollination system

The pollination system was decided on the basis of observations on anthesis. The presence of overlapping of the male and female phase was taken as an indication for self pollination whereas the presence of a clear interphase was considered as an indication for cross pollination.

(x) Alternate bearing habit

Annual nut yield for two consecutive years in each palm was assessed and a reduction in yield above 70 per cent was considered as alternate bearing habit, between 30 and 70 per cent as intermediate and a reduction in yield below 30 per cent as regular.

3.2.2 Seednut collection

Seednuts were collected during the period from January to April 1989 in three harvests.

Forty four seednuts were collected from each of the ten palms belonging to the five varieties/types. The malformed and barren nuts were rejected. All the seednuts collected were given the respective identity numbers. From each group of 44 nuts, four were randomly selected for fruit component analysis (Mathew et al., 1978). The remaining seednuts from each palm of the five varieties/types were stored in sand in a room with sufficient aeration till June 1989 for sowing.

3.2.3 Fruit component analysis

Following observations were recorded on the nuts selected for fruit component analysis.

(i) Polar diameter of nut

The length of the nut from one pole to the other measured by setsquare blocking of the nut and measuring the distance using a meter scale, gave the polar diameter of the nut in centimetres.

(ii) Equatorial diameter of nut

The breadth of the nut at the middle portion measured by setsquare blocking of the nut and measuring the distance using a meter scale gave the equatorial diameter of the nut in centimetres.

(iii) Thickness of husk

This was recorded by piercing the husk with a sharp needle till it reached the shell and the mean length of the needle from the shell to the outer surface of the husk pierced at the three flat surfaces of the nut gave the thickness of husk in centimetres.

(iv) Weight of unhusked nut

Unhusked nuts were weighed in a pan balance and mean weight expressed in kilograms.

(v) Weight of husked nut

The nuts were husked, cleaned, weighed and mean weight expressed in grams.

(vi) Weight of opened nut

The nut was split into two halves and the weight expressed in grams.

(vii) Volume of nut water

The volume of water in the nut was measured using a measuring cylinder and the mean volume expressed in millilitres.

(viii) Thickness of meat

Meat thickness was measured using vernier calipers at three different places on the circumference of the opened nut and the mean meat thickness expressed in centimetres.

(ix) Diameter of eye

The hole on the shell corresponding to the soft eye was carefully cleaned and diameter recorded along two axes. Mean of these two values gave the mean eye diameter of a nut expressed in centimetres.

(x) Weight of embryo

Embryo from the soft eye of the nut was scooped out and weighed and the weight expressed in grams.

(xi) Weight of shell

Weight of shell was recorded after removing the kernel and the weight expressed in grams.

(xii) Weight of kernel

The difference in weight of opened nut and weight of shell gave the weight of kernel expressed in grams.

(xiii) Weight of copra

The kernel excised out of the shell was dried at an air temperature of 60°C for three days and the weight recorded in grams.

(xiv) Oil content

The copra from each of the four nuts from every palm was cut into small pieces and a random sample of 0.5 g of copra was taken from each nut for estimation of oil content. The percentage was estimated by the cold percolation method (Kartha and Sethi, 1957). One sample was analysed from each nut making a total of four samples from a palm. The mean value gave the oil percentage.

(xv) Husk/nut ratio

The difference in weight of unhusked nut and husked nut divided by weight of unhusked nut gave the husk/nut ratio.

3.2.4 Selfing of mother palms

Selfing was done in each selected palm of all the five varieties/types.. In cases where fresh pollen was not available in the same palm, pollen collection, processing and preservation were done as suggested by Nair (1985).

3.2.4.1 Comparison of open pollinated and selfed nuts

Four selfed seednuts were obtained from each palm of all the five varieties/types. The weight of kernel and embryo of selfed nuts were compared with those of open pollinated nuts in the respective groups for detecting prepotency and inbreeding depression.

3.2.5 Seedling progeny analysis

A Compact Family Block Design (5x10) with four replications and 10 seedlings per plot was employed. Each replication consisted of five treatments and each treatment had 100 seednuts (10 seednuts each from 10 palms). On the whole 2000 seednuts belonging to the five varieties/types were sown in the nursery and the data in respect of seedling attributes were recorded.

i) Germination of seednuts

Germinated nuts were scored at weekly intervals starting from the first week after sowing. Emergence of beak at the stalk end was considered as the sign of germination. Germination counts were continued upto six months. Other biometric observations were limited to seedlings emerged from seednuts germinated within the period of six months. Percentage germination was calculated as follows

$$\text{Germination percentage} = \frac{\text{germinated nuts}}{\text{Total number of nuts sown}} \times 100$$

ii) Days taken for germination

Number of days taken for germination of each seednut was recorded from the date of sowing for a period of six months.

3.2.5.1 Seedling growth analysis

Observations on seven characters were recorded on all the seedlings in the nursery at 5^{th} and 9^{th} months after germination and also at 12^{th} month after sowing from June 1989 to May 1990.

i) Seedling height (cm)

Height of seedling was measured from the base of the emerging shoot to the highest extremity, using a graduated meter scale.

ii) Number of leaves

Number of leaves present on each seedling was recorded.

iii) Girth at collar (cm)

A non-extendable string (twine) was used to measure collar girth. The string was wound three times around the collar, unwound and length measured. This measurement divided by three gave the girth at collar.

iv) Number of plants with split leaves

The seedlings were continuously observed for splitting of leaf into leaflets and the observations were recorded as number of plants with split leaves at 12^{th} month after sowing.

v) Total leaf area at 5^{th} and 9^{th} month

An empirical formula developed by Ramadasan et al. (1980) was used in calculating leaf area, according to which

$$Y = a + b X$$

where Y = leaf area

a = 27.3861

b = 0.6139

X = product of length and breadth of lamina in the case of unsplit leaf.

Area of each leaf was calculated separately and added up to give the total leaf area.

vi) Chlorophyll at 5th and 9th month

The topmost fully opened leaf in a seedling was selected. In such a leaf, two leaflets each from either side of the rachis at the middle portion of the leaf were taken. The tip, the basal portion and the midrib of the leaflets were removed and the middle portion of all the four leaflets were cut into small pieces and mixed together. From this a random sample of 1g was taken for chlorophyll estimation. The chlorophyll estimation was done based on the method suggested by Mahadevan and Sridhar (1982).

vii) Pigmentation on the petiole of seedlings

Pigmentation on the petiole of seedlings was scored as per standards fixed in the "Nickerson Color Fan (1957)".

3.2.6 Statistical analysis

3.2.6.1 Mother palm characters

Ten palms each of the five varieties/types were selected for the study and from these palms the various characters viz. number of leaves, number of bunches and spadices, number of unopened spadices, number of female flowers per bunch, number of nuts per bunch and number of nuts per palm per year were recorded for 2 consecutive years. These were subjected to analysis of variance to test the significance of difference among the five varieties/types with respect to the characters mentioned above.

3.2.6.2 Fruit component analysis

From each of the selected palm, four nuts were randomly selected and the observations recorded on polar diameter of nut, equatorial diameter of nut, thickness of husk, weight of unhusked nut, weight of husked nut, weight of opened nut, volume of nut water, thickness of meat, diameter of eye, weight of embryo, weight of shell, weight of kernel, weight of copra, oil content and husk/nut ratio were subjected to analysis of variance to test the significance of difference among the five varieties/types.

3.2.6.2.1 Comparison of open pollinated and selfed nuts

The significant difference in the nut characters viz., weight of embryo and kernel, if any exist between open pollinated and selfed nuts, was tested by ANOVA as follows

Source	df
Open pollinated vs selfed	1
Between nuts within open pollinated palms	9
Between nuts within selfed palms	9
Error	60
Total	79

3.2.6.3 Seedling progeny analysis

The data collected from progeny row trial involving five (f) families (varieties/types) with 100 (p) progenies each in Compact Family Block design with four (r) replications were subjected to analysis of variance as follows.

Abstract of ANOVA

i) Family analysis

source	df	MS
Between replications	r-1	MSR
Between families	f-1	MSF
Error	(r-1) (f-1)	MSE_1

ii) Progeny analysis for each family

source	df	MS
Between replications	r-1	MSR
Between progenies within family	p-1	MSP
Error	(r-1) (p-1)	MSE

If significant differences were detected between progenies within a family, the genetic variance (σ_g^2) between progenies were separated out

$$\sigma_g^2 = \frac{MSP - MSE}{r}$$

The homogeneity of error variances of families was tested using Bartlett's χ^2-test of significance given by

$$\chi^2_{f-1} = \frac{n(f \log S^{-2} - E \log S_I^2)}{1 + \frac{f+1}{3nf}}$$

where n = (r-1) (p-1), the error df for each family , S^{-2} is the mean of error variances.

If homogeneity of error variances was detected then pooled analysis was carried out as follows

source	df	MS
Between replications	r-1	MSR
Between families	f-1	MSF
Error (1)	(r-1) (f-1)	MSE_1
Between progenies within families	f (p-1)	MSP
Error (2)	f (p-1) (r-1)	MSE_2

The above analysis of variance helps to detect the significant difference among families, between progenies of the same family and between progenies of different families (Panse and Sukhatme, 1957; Prem Narain et al.,1979).

3.2.6.3.1 Seedling vigour index

The total amount of information in a data is defined as the inverse of the variance which is a measure of spread of observations from the central value say, the arithmetic mean. If V_x is the variance estimated for the character X from the data, then $\frac{1}{V_x}$ is the amount of information in the data. This quantity of information is used as a weight to the character x to develop a vigour index with respect to a given seedling progeny.

If X_{i1}, X_{i2} ----- X_{ik} are the means of K characters and w_1, w_2----w_k are the weights where $w_i = \frac{1}{V_{xi}}$ the quantities of information in the data with respect to these characters, the seedling vigour index of the i^{th} progeny is estimated as

$P_i = w_1 x_{i1} + w_2 x_{i2} + \cdots\cdots\cdots w_k x_{ik}$, P_i being the vigour index of i^{th} seedling.

The seedling vigour index of the progenies belonging to the five varieties/types was computed based on five traits viz., days taken for germination (X_1), height of seedling (X_2), number of leaves (X_3), girth at collar (X_4) and total leaf area (X_5). The progenies were then ranked on the basis of their vigour indices.

3.2.6.3.2 Recovery of quality seedlings

Recovery of quality seedlings was estimated based on the index score method of Singh and Chaudhary (1979).

The range of variability for each of the three traits viz., height of seedling, number of leaves and girth at collar was classified into three groups using the criterion $\bar{X} \pm 2SE$ (Table 2).

Table 2. Index score for the various classes

Class	Class interval	Index
1	Below (Mean - 2 SE)	1
2	Between (Mean ± 2 SE)	2
3	Above (Mean + 2 SE)	3

Individual seedlings within values in the range of any of the three classes are assigned the respective scores. The scores for the three traits for each seedling were then added. The index score values for individual seedlings thus ranged from 3 to 9. Seedlings with an index score greater than 6 indicating a moderate to high vigour for the combination of traits were considered as quality seedling based on the recommendations of Kannan and Nambiar (1979). Based on this grouping, the percentage of quality seedlings to total number of seednuts sown was worked out. The yard-stick for recovery of quality seedlings from total number of seednuts sown is 60-65 per cent as per package of practices recommendations (Anonymous, 1981). The data on percentage recovery of quality seedlings to total number of seednuts sown were subjected to analysis of variance.

3.2.6.4 Pigmentation on leaf stalk,nut and petiole

Pigmentation on leaf stalk and nuts of mother palms and petiole of seedlings was scored as per the standards fixed in the colour chart "Nickerson Color Fan (1957)" available at C.P.C.R.I., Kasaragod. The total number of mother palms/seedlings having the same colour index for leaf stalk, nut/petiole within a variety/type was found out and its percentage obtained based on total number of mother palms/seedlings in that variety/type.

3.2.6.5 Analysis of variance and covariance

The data were subjected to analysis of variance and covariance in accordance with the design of the experiment. From this the following components of variance/covariance were estimated as follows (Prem Narain, 1990).

$$\hat{\sigma}_e^2 = \text{environmental variance} = MSE$$

$$\hat{\sigma}_g^2 = \text{genotypic variance} = \frac{MST - MSE}{r}$$

$$\hat{\sigma}_p^2 = \text{phenotypic variance}$$

$$= \hat{\sigma}_g^2 + \hat{\sigma}_e^2$$

where MST and MSE are the mean squares for treatments and error respectively and r is the number of replications.

$$\hat{\sigma}_{eij} = \text{environmental covariance of } X_i \text{ and } X_j$$

$$= MSPEij$$

$$\hat{\sigma}_{gij} = \text{genotypic covariance of } X_i \text{ amd } X_j$$

$$= \frac{(MSPTij - MSPEij)}{r}$$

$$\hat{\sigma}_{pij} = \text{phenotypic covariance of } X_i \text{ and } X_j$$

$$= \hat{\sigma}_{gij} + \hat{\sigma}_{eij}$$

Genotypic coefficient of variation (GCV) $= \dfrac{\sigma_g}{\bar{X}} \times 100$

Phenotypic coefficient of variation (PCV) $= \dfrac{\sigma_p}{\bar{X}} \times 100$

3.2.6.5 Heritability coefficient (h_b^2) in broad sense

Heritability in the broad sense was estimated as a percentage following Prem Narain (1990) as

$$h_b^2 = \frac{\sigma_g^2}{\sigma_p^2} \times 100$$

3.2.6.6 Genetic Advance Under selection (G.A)

Genetic advance as percentage of mean under selection was estimated as follows (Allard, 1960)

$$G.A. = \frac{K\, h_b^2\, \sigma_p}{\bar{X}}$$

where K = selection differential which is 2.06 at 5% intensity of selection

p = phenotypic standard deviation

$\bar{X}$ = mean of the character x

h_b^2 = heritability in broad sense

3.2.6.7 Correlation coefficients

Correlation coefficients were estimated as follows (Prem Narain, 1990)

Genotypic correlation coefficient $r_{gij} = \dfrac{\sigma_{gij}}{\sigma_{gi}\ \sigma_{gj}}$

Environmental correlation coefficient $r_{eij} = \dfrac{\sigma_{eij}}{\sigma_{ei}\ \sigma_{ej}}$

Phenotypic correlation coefficient $r_{pij} = \dfrac{\sigma_{pij}}{\sigma_{pi}\ \sigma_{pj}}$

3.2.6.8 Direct and indirect effects (Path analysis)

Path coefficient method invented by Wright (1923) is applied to study the cause and effect relationship in a system of correlated variables.

Let a variable Y be determined completely and linearly by a set of n variables X_1, X_2, X_3, --------- X_n. The solution of a system of simultaneous equations provide the estimates of path coefficients, which are the standardised partial regression coefficients, where the system is given by

$$\underset{\sim}{\underline{Rij}}\ \underline{Pi} = \underline{Riy}$$

Rij is the n x n matrix of intercorrelations

Pi is the vector of path coefficients and

Riy is the vector of correlations between X_i and Y, i = 1, 2,----n.The indirect effect of X_i on Y via X_j is given by rij Pj. The residual R is determined from the relation

$$R^2 = (1- rij\ Pi).$$

3.6.2.9 D^2 analysis

A measure for group distance based on multiple characters was given by Mahalanobis (1928). With X_1, X_2, X_3-------X_p as the multiple measurements available on each population and d_1, d_2 ------- d_p as $(\bar{X}_1^1 - \bar{X}_1^2)$, $(\bar{X}_2^1 - \bar{X}_2^2)$, -------- $(\bar{X}_p^1 - \bar{X}_p^2)$ respectively being the difference in the means of two populations, Mahalanobis D^2 statistic is estimated as follows

$$D^2 = b_1d_1 + b_2d_2 + \text{--------}\ b_pd_p..(1)$$

Here $\bar{X}_i^1$ is the mean value of the i^{th} character in the first population and $\bar{X}_i^2$ is the mean value of the i^{th} character in the second population. The b_i values are estimated such that the ratio of the variance between populations to the variance within populations is maximised.

In terms of variances and covariances, the D^2 value is obtained as follows

$$pD^2 = \Sigma_i \Sigma_j \; W^{ij} (\bar{X}_i^1 - \bar{X}_i^2)(\bar{X}_j^1 - \bar{X}_j^2) \ldots\ldots\ldots (2)$$

where, W^{ij} is the inverse of the estimated variance covariance matrix.

The estimation of D^2 values by the formula given in equation (2) is very complicated when the number of characters studied is large. In this study, four seedling characters viz., height of seedling, number of leaves, girth at collar and total leaf area were utilized for the D^2 analysis. The computation was simplified by transforming the characters to render them independent and expressing them in terms of their respective standard errors. The computation of D^2 values thus reduced to simple summation of the differences in mean values of the various characters of the two populations that is, Σd_i^2. Therefore the correlated variables were first transformed to uncorrelated ones and the D^2 values were worked out. Transformation was done using pivotal condensation method. When Y_1, Y_2 ----- Y_p were the transformed variates, for each combination, the mean deviation, i.e., $\bar{Y}_i^1 - \bar{Y}_i^2$ with $i = 1,2$ ----- p was computed and the D^2 was calculated as the sum of the squares of these deviations, ie., $\Sigma(\bar{Y}_i^1 - \bar{Y}_i^2)^2$.

Test of significance of D^2 values

The D^2 value obtained for a pair of populations is taken as the calculated value of χ^2 and is tested against the tabulated value of χ^2 for p degrees of freedom, p being the number of characters considered.

Grouping of the mother palms into clusters

The Tochers method was followed. The first step was to arrange the mother palms in the order of their relative distances from each other. The two mother palms having the smallest distance from each other were considered first, to which a third mother palm having the smallest average D^2 value from the first two mother palms was added. Then the nearest fourth mother palm was added and so on. At a certain stage,when it was found that there was a disrupt increase in the average D^2 of the cluster (the cutoff value being 3972146 in the present experiment), on adding a particular mother palm that palm was excluded from that cluster. Formation of the second cluster was then initiated with another pair of mother palms which had the next higher D^2 value to that of the first pair in the first cluster and when the average D^2 values exceeded 3972146, a third cluster was initiated. The process was continued in this manner until all the 50 mother palms were included in one or the other cluster.

Average intra-cluster distance

For the measure of intra-cluster distances, the formula used was ΣD_i^2 /N where ΣD_i^2 is the sum of distances between all possible combinations (N) of the mother palms included in a cluster.

Average inter-cluster distance

The distances between all possible combinations of the clusters obtained were worked out. For the purpose, the sum of distances between all possible combinations of the mother palms in a pair of clusters at a time was taken. The sum of D^2 values obtained, divided by the product of the number of mother palms in each cluster gave the inter cluster distance between the particular pair of clusters. The average inter and intra cluster distances were then tabulated, based on which a cluster diagram was drawn to scale using the D = ($\sqrt{D^2}$) values given in ('00).

RESULTS

4. RESULTS

4.1 Mother palm characters

The mean values of six mother palm characters are given in Table 3. The five coconut varieties/types showed significant differences among themselves for five characters. The three Komadan generations expressed the maximum values for all these characters.

The second and third generations of Komadan showed the maximum values for number of leaves (34.35 and 33.75 respectively) followed by the first generation Komadan (32.60). They were significantly superior to WCT for this character. NCD (31.05) was found superior to WCT but on par with first generation Komadan. The second and third generations of Komadan were significantly superior to NCD for this character.

No significant difference in the number of bunches and spadices were seen among the three generations of Komadan but this was significantly high in Komadan compared to NCD (11.30) and WCT (11.05) which were on par.

The number of unopened spadices did not show any significant difference among all the five coconut varieties/types.

The first and third generations of Komadan have given the maximum number of nuts per bunch (13.40 and 12.75 respectively) followed by second generation Komadan (9.90). The WCT and NCD showed significantly inferior values (9.10 and 8.65 respectively) for this character when compared to the first and third generations of Komadan and were on par with the second generation Komadan.

The first generation Komadan was found significantly superior in the number of female flowers per bunch to all other varieties/types (45.15). The second and third generations of Komadan (31.5 and 33.25 respectively) were on par with WCT (27.70). But they were significantly superior to NCD. However, WCT and NCD were found to be on par for this character.

Maximum nut production per year was found to be in the first generation Komadan (192.20) which was found significantly superior to all other varieties/types. The second and third generations of Komadan were on par for this character (135.50 and 160.20 respectively)

Table 3. Mean values of six mother palm characters

Variety/ type	Number of leaves	Number of bunches and spadices	Number of unopened spadices	Number of nuts per bunch	Number of female flowers per bunch	Number of nuts per palm per year
KI	32.60	14.50	3.20	13.40	45.15	192.20
KII	34.35	13.70	3.00	9.90	31.50	135.50
KIII	33.75	13.90	3.25	12.75	33.25	160.20
WCT	28.35	11.05	3.10	9.10	27.70	102.60
NCD	31.05	11.30	2.85	8.65	23.40	107.80
$F_{4,45}$	8.39**	9.72**	0.68	9.83**	13.00**	15.26**
SE	0.831	0.512	0.195	0.678	2.266	9.569
CD(0.05)	2.368	1.458	--	1.932	6.456	27.269

** - Significant at 1 per cent level.

Table 4. Genetic parameters of mother palm characters

Sl. No.	Characters	Phenotypic coefficient of variation (%)	Genotypic coefficient of variation (%)	Heritability (%)	Genetic advance (% of mean)
1	Number of leaves	10.82	7.05	42.46	9.47
2	Number of bunches and spadices	17.09	11.59	45.98	16.18
3	Number of unopened spadices	16.46	N.E	N.E	N.E
4	Number of nuts per bunch	27.25	18.66	46.88	26.31
5	Number of female flowers per bunch	33.00	24.38	55.00	37.39
6	Number of nuts per palm per year	33.75	25.87	58.77	40.85

N.E - Not Estimable

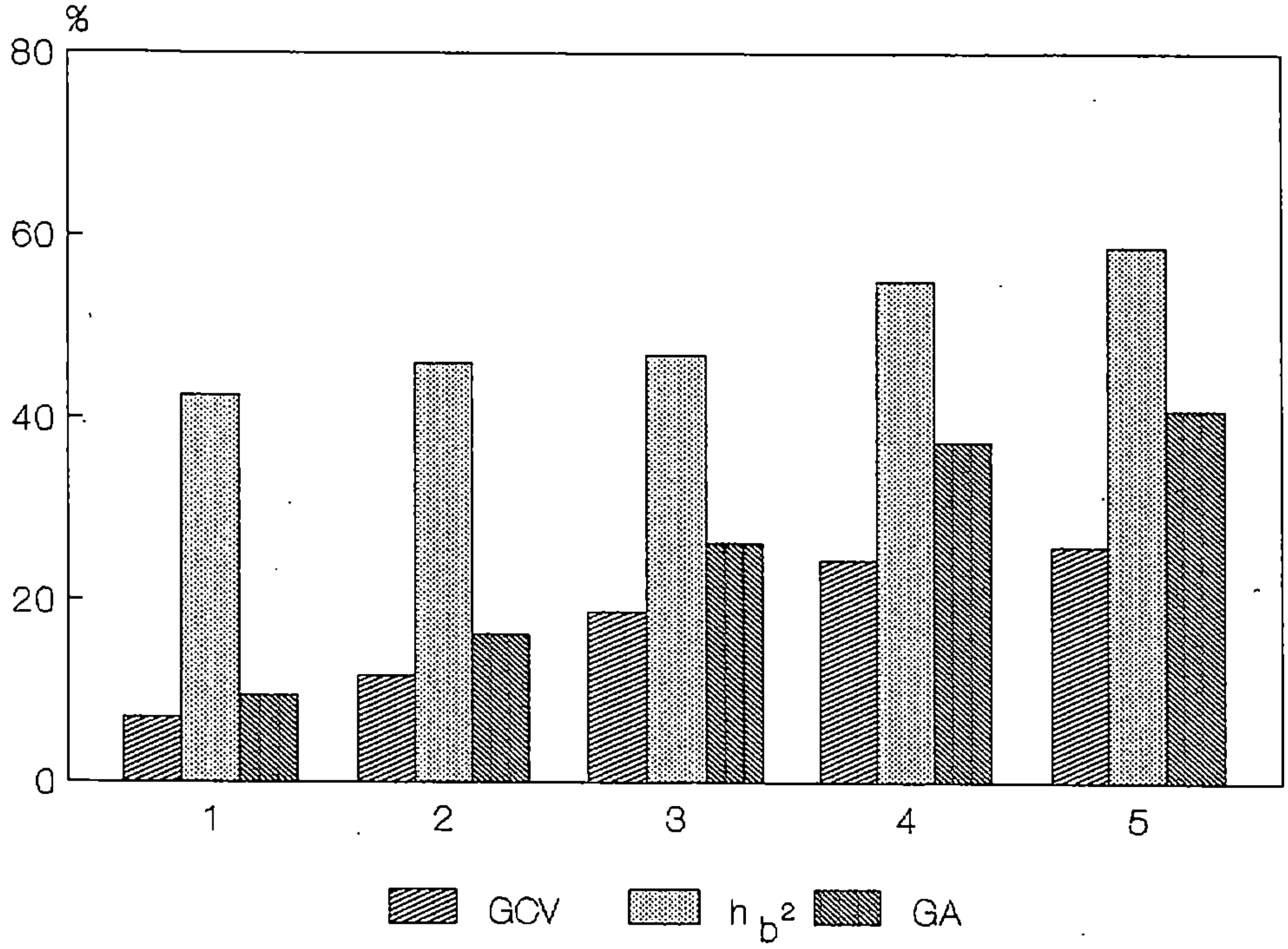
but they were significantly superior to both WCT and NCD (102.60 and 107.80 respectively), the nut production being significantly low in these varieties compared to Komadan types.

4.1.1 Genetic parameters of mother palm characters

The phenotypic and genotypic coefficients of variation, heritability and genetic advance for the six mother palm characters were estimated and presented in Table 4 (Fig. 2).

Number of nuts per palm per year showed the highest phenotypic coefficient of variation (33.75 per cent) followed by number of female flowers per bunch (33 per cent) and number of nuts per bunch (27.25 per cent). The lowest value was recorded for number of leaves (10.82 per cent). The genotypic coefficient of variation also was highest for number of nuts per palm per year (25.87 per cent) and lowest for number of leaves (7.05 per cent). The genotypic coefficient of variation was not estimable for number of unopened spadices as the genotypic variance was not estimable and this character was mainly influenced by the environment.

Fig.2. Genetic parameters of mother palm characters



The number of nuts per palm per year showed the maximum heritability (58.77 per cent) and genetic advance (40.85 per cent). The number of female flowers per bunch showed the next highest values of heritability (55.00 per cent) and genetic advance (37.39 per cent). Number of nuts per bunch showed a heritability of 46.88 per cent but the genetic advance for this character was low (26.31 per cent). Similar trend in heritability and genetic advance was shown for number of leaves and number of bunches and spadices. The heritability and genetic advance were not estimable for number of unopened spadices.

4.1.2 Correlation coefficients among mother palm characters

The correlation coefficients among mother palm characters in respect of individual varieties/types and over the five varieties/types are given in Table 5.

In the first generation Komadan mother palms, number of nuts per bunch, number of female flowers per bunch and nut yield per year showed significant positive correlation among themselves. Number of leaves per palm showed significant negative correlation with number of unopened spadices.

Table 5. Correlation coefficients among mother palm characters

Character	K I	K II	KIII	WCT	NCD	Over the five varieties/types
x_1 Vs x_2	0.3279	0.2453	0.3241	-0.0073	0.2985	0.3468**
x_1 Vs x_3	-0.6583**	0.4927*	0.0471	0.3547	0.3422	0.1726
x_1 Vs x_4	-0.1560	0.1170	-0.2930	0.1083	0.0469	0.1310
x_1 Vs x_5	-0.3340	-0.1758	-0.1698	-0.0796	0.1164	0.0307
x_1 Vs x_6	0.0155	-0.0014	-0.2156	0.1029	0.1989	0.1917
x_2 Vs x_3	-0.4336	0.0000	-0.1799	0.3332	0.2334	0.0673
x_2 Vs x_4	-0.1969	0.6854**	-0.0616	0.0404	-0.1969	0.5273**
x_2 Vs x_5	-0.0116	0.6264**	0.2414	0.0174	-0.4286	0.4885**
x_2 Vs x_6	0.2344	0.7502**	0.1062	0.6496**	0.1350	0.7357**
x_3 Vs x_4	0.0869	0.0440	0.3585	0.4446*	-0.0633	0.1533
x_3 Vs x_5	0.1890	0.0942	-0.0873	0.1884	-0.1416	0.1095
x_3 Vs x_6	-0.1381	-0.0594	0.4374	0.5459*	-0.0486	0.1136
x_4 Vs x_5	0.8434**	0.7868**	0.4516*	0.7288**	0.6532**	0.7429**
x_4 Vs x_6	0.8664**	0.9432**	0.9079**	0.7695**	0.8770**	0.9150**
x_5 Vs x_6	0.8217**	0.8642**	0.5412*	0.5317*	0.4462*	0.7899**

x_1 - Number of leaves
x_2 - Number of bunches and spadices
x_3 - Number of unopened spadices
x_4 - Number of nuts per bunch
x_5 - Number of female flowers per bunch
x_6 - Number of nuts per palm per year

* - Significant at 5 per cent level.

** - Significant at 1 per cent level.

In the second generation Komadan, number of bunches and spadices, number of nuts per bunch, number of female flowers per bunch and nut yield per year showed significant positive correlation among themselves but no significant correlation was noticed with number of leaves and number of unopened spadices. Number of leaves showed significant positive correlation only with number of unopened spadices.

In the third generation Komadan, significant positive inter correlations were shown between number of nuts per bunch, number of female flowers per bunch and nut yield per year. There was no significant correlation with the other three characters viz., number of leaves, number of bunches and spadices and number of unopened spadices.

In WCT number of bunches and spadices showed significant positive correlation with nut yield. Number of nuts per bunch showed significant positive correlation with all characters except number of leaves and number of bunches and spadices. Number of female flowers per bunch showed high positive correlation with number of nuts per bunch and nut yield. Nut yield showed significant positive correlation with all characters except number of leaves.

In NCD, number of nuts per bunch, number of female flowers per bunch and nut yield per year showed significant positive correlation among themselves. The other characters showed no significant correlations.

The correlation coefficients estimated over the five varieties/types showed number of bunches and spadices to be significantly and positively correlated with all characters except number of unopened spadices. Number of nuts per bunch, number of female flowers per bunch and nut yield per year showed significant positive correlation among themselves and with number of bunches and spadices. Number of unopened spadices showed no significant correlation with any of the mother palm characters.

4.1.3 Pollination system and bearing habit of mother palms

The pollination system and bearing habit of mother palms are given in Table 6.

In first generation Komadan, absence of interphase in anthesis was noticed in two out of the ten mother palms selected for the study. Yield of nuts recorded for two consecutive years showed that one palm exhibited an

Table 6 . Pollination system and bearing habit of mother palms

(i) First generation Komadan

Treatment No.	Type of anthesis	Yield of nuts 1st year	2nd year	Bearing habit
K 1	Presence of interphase	195	170	Regular
K 2	Presence of interphase	224	190	Regular
K 3	Presence of interphase	270	198	Regular
K 4	Absence of interphase	180	185	Regular
K 5	Presence of interphase	185	160	Regular
K 6	Presence of interphase	255	195	Regular
K 7	Presence of interphase	247	90	intermediate
K 8	Absence of interphase	225	185	Regular
K 9	Presence of interphase	124	110	Regular
K 10	Presence of interphase	256	200	Regular

(ii) Second generation Komadan

K 11	Absence of interphase	204	130	intermediate
K 12	Presence of interphase	160	3	Alternate
K 13	Absence of interphase	103	180	intermediate
K 14	Absence of interphase	148	110	Regular
K 15	Presence of interphase	153	160	Regular
K 16	Absence of interphase	165	152	Regular
K 17	Presence of interphase	230	5	Alternate
K 18	Presence of interphase	156	158	Regular
K 19	Presence of interphase	210	18	Alternate
K 20	Presence of interphase	185	80	intermediate

(iii) Third generation Komadan

K 21	Presence of interphase	280	105	intermediate
K 22	Presence of interphase	190	196	Regular
K 23	Absence of interphase	190	90	intermediate
K 24	Absence of interphase	180	132	Regular
K 25	Presence of interphase	160	142	Regular
K 26	Presence of interphase	130	130	Regular
K 27	Absence of interphase	120	90	Regular
K 28	Absence of interphase	165	164	Regular
K 29	Presence of interphase	168	134	Regular
K 30	Presence of interphase	260	184	Regular

(iv) West Coast Tall

W 1	Presence of interphase	120	204	intermediate
W 2	Presence of interphase	148	104	Regular
W 3	Presence of interphase	98	66	Regular
W 4	Presence of interphase	90	86	Regular
W 5	Presence of interphase	102	60	intermediate
W 6	Presence of interphase	125	63	intermediate
W 7	Presence of interphase	158	69	intermediate
W 8	Presence of interphase	105	110	Regular
W 9	Presence of interphase	108	40	intermediate
W 10	Presence of interphase	126	70	intermediate

(v) Natural Cross Dwarf

N1	Absence of interphase	150	123	Regular
N2	Absence of interphase	118	24	Alternate
N3	Absence of interphase	187	16	Alternate
N4	Absence of interphase	240	50	Alternate
N5	Absence of interphase	139	49	Alternate
N6	Absence of interphase	176	18	Alternate
N7	Absence of interphase	163	5	Alternate
N8	Absence of interphase	208	6	Alternate
N9	Absence of interphase	266	36	Alternate
N10	Absence of interphase	148	34	Alternate

intermediate bearing habit while the rest of the palms were regular bearers.

In second generation Komadan, interphase was absent in anthesis in four out of the ten palms studied. The nut yield data for two years showed three out of the ten palms to be alternate bearers, three intermediate bearers and the remaining were regular bearers.

In third generation Komadan, out of the ten palms studied four exhibited absence of interphase in anthesis. The nut yield data for two years showed that all the palms were regular bearers except two which showed intermediate bearing nature.

In WCT, presence of interphase in anthesis was noticed in all the palms. The yield of nuts for two years showed four out of the ten palms to be regular bearers while the remaining showed intermediate bearing tendency.

In NCD, all the palms showed absence of interphase in anthesis. All the palms except one were found to be alternate bearers of varying degrees.

4.1.4 Pigmentation on leaf stalk in mother palms

The percentage analysis of pigmentation on leaf stalk in mother palms is given in Table 7 (Fig. 3).

In first generation Komadan, 90 per cent of the palms had leaf stalk with olive shade ranging from 5 GY 4/3 (moderate olive green) to 7.5 Y 4/3 (moderate olive) while 10 per cent had moderate brown leaf stalk. In the second and third generations of Komadan and NCD, all the palms had leaf stalks with olive shade. In WCT, 90 per cent of the palms had leaf stalks with olive shade while 10 per cent had dark greyish green colour (10 GY 3/2).

4.1.5 Pigmentation on nut in mother palms

Variations in the colour of nuts are shown in Figure 4. Table 8 (Fig. 5) shows the percentage analysis of pigmentation on nuts in mother palms.

In the first generation Komadan, 70 per cent of the palms had moderate brown nuts, 20 per cent moderate olive brown and 10 per cent greyish brown nuts. In the second generation Komadan also, 70 per cent of the palms had moderate brown nuts and 30 per cent moderate olive brown nuts. In

Table 7. Pigmentation on leaf stalk in mother palms

Colour index	Colour	Percentage of palms				
		KI	KII	KIII	WCT	NCD
10 GY 3/2	Dark greyish green	--	--	--	10	--
5 GY 4/3	Moderate olive green	30	20	20	40	60
5 Y 5/6	Light olive	50	40	60	20	20
7.5 Y 4/3	Moderate olive	10	40	20	30	20
5 YR 3/3	Moderate brown	10	--	--	--	--

Table 8. Pigmentation on nut in mother palms

Colour index	Colour	Percentage of palms				
		KI	KII	KIII	WCT	NCD
2.5 Y 4/4	Moderate olive brown	20	30	40	10	10
2.5 Y 5/5	Light olive brown	--	--	--	--	10
10 Y 4/3	Moderate olive	--	--	--	10	30
2.5 YR 4/7	Strong brown	--	--	--	10	--
5 YR 3/3	Moderate brown	10	30	30	--	10
7.5 YR 3/2	Greyish brown	10	--	--	--	--
7.5 YR 4/5	Moderate brown	60	40	30	--	10
2.5 GY 4/3	Moderate olive green	--	--	--	30	30
5 GY 3/2	Greyish olive green	--	--	--	40	--

Fig.3. Pigmentation of leaf stalk in mother palms

Colour index	Colour
10 GY 3/2	Dark greyish green
5 GY 4/3	Moderate olive green
5 Y 5/6	Light olive
7.5 Y 4/3	Moderate olive
5 YR 3/3	Moderate brown

Fig.3. Pigmentation on leaf stalk in mother palms

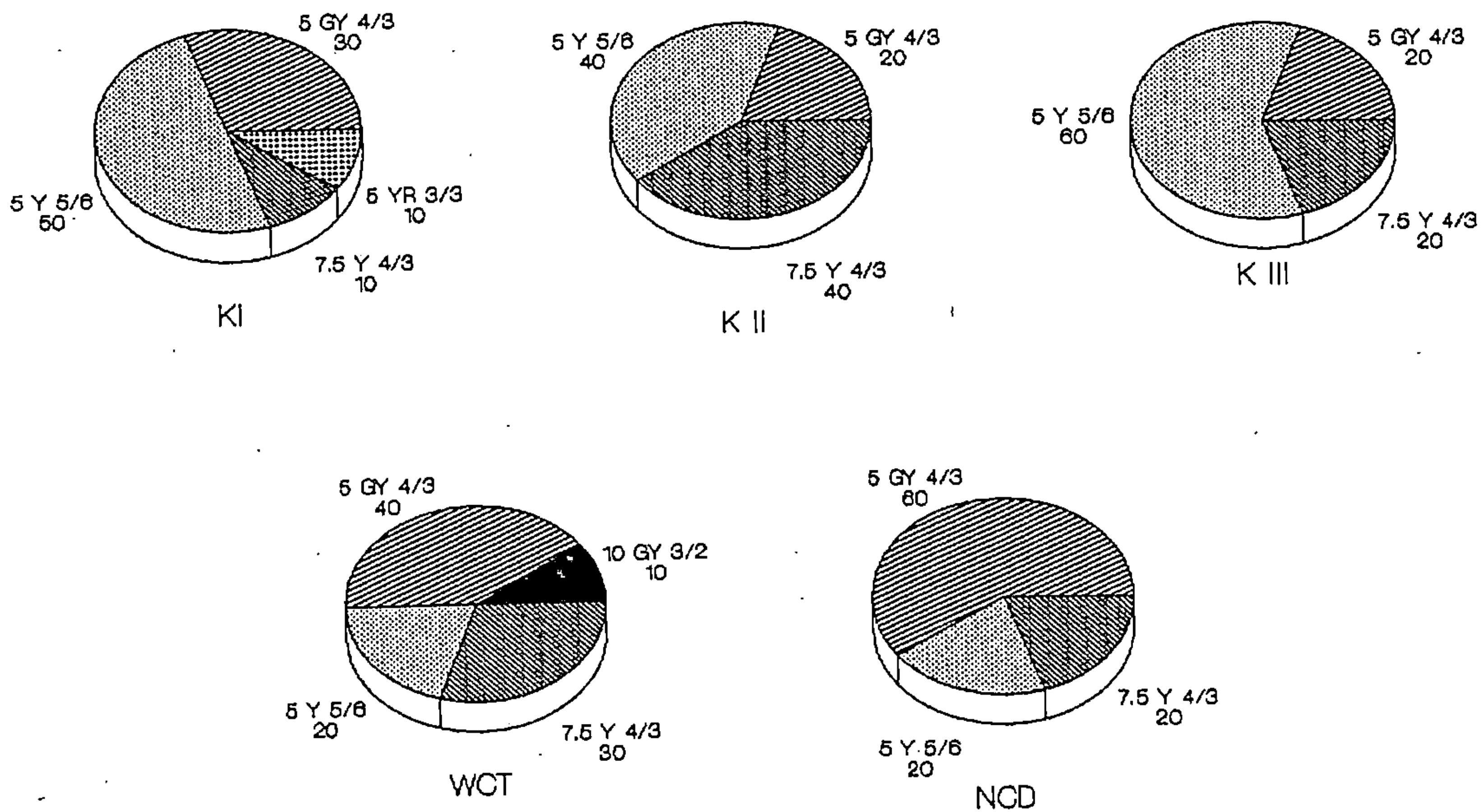


Fig.4. Variations in the colour of nuts

NO.	Colour index	Colour
1.	10 Y 4/3	moderate olive
2.	7.5 YR 7/11	strong orange yellow
3.	7.5 YR 6/9	dark orange yellow
4.	2.5 Y 4/4	moderate olive brown
5.	7.5 YR 4/5	moderate brown
6.	5 YR 3/3	moderate brown
7.	2.5 Y 5/5	light olive brown
8.	7.5 YR 3/2	greyish brown
9.	2.5 GY 3/1	greyish olive green
10.	2.5 YR 4/7	strong brown
11.	2.5 GY 4/3	moderate olive green
12.	5 GY 3/2	greyish olive green

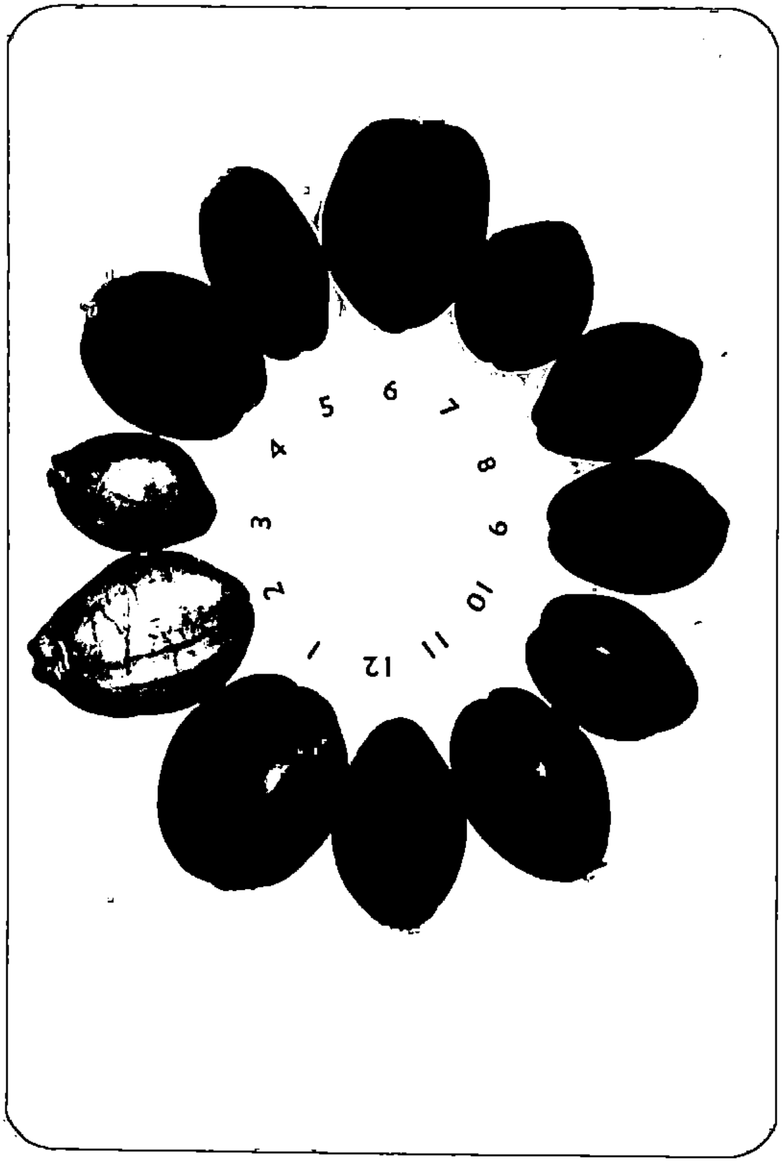
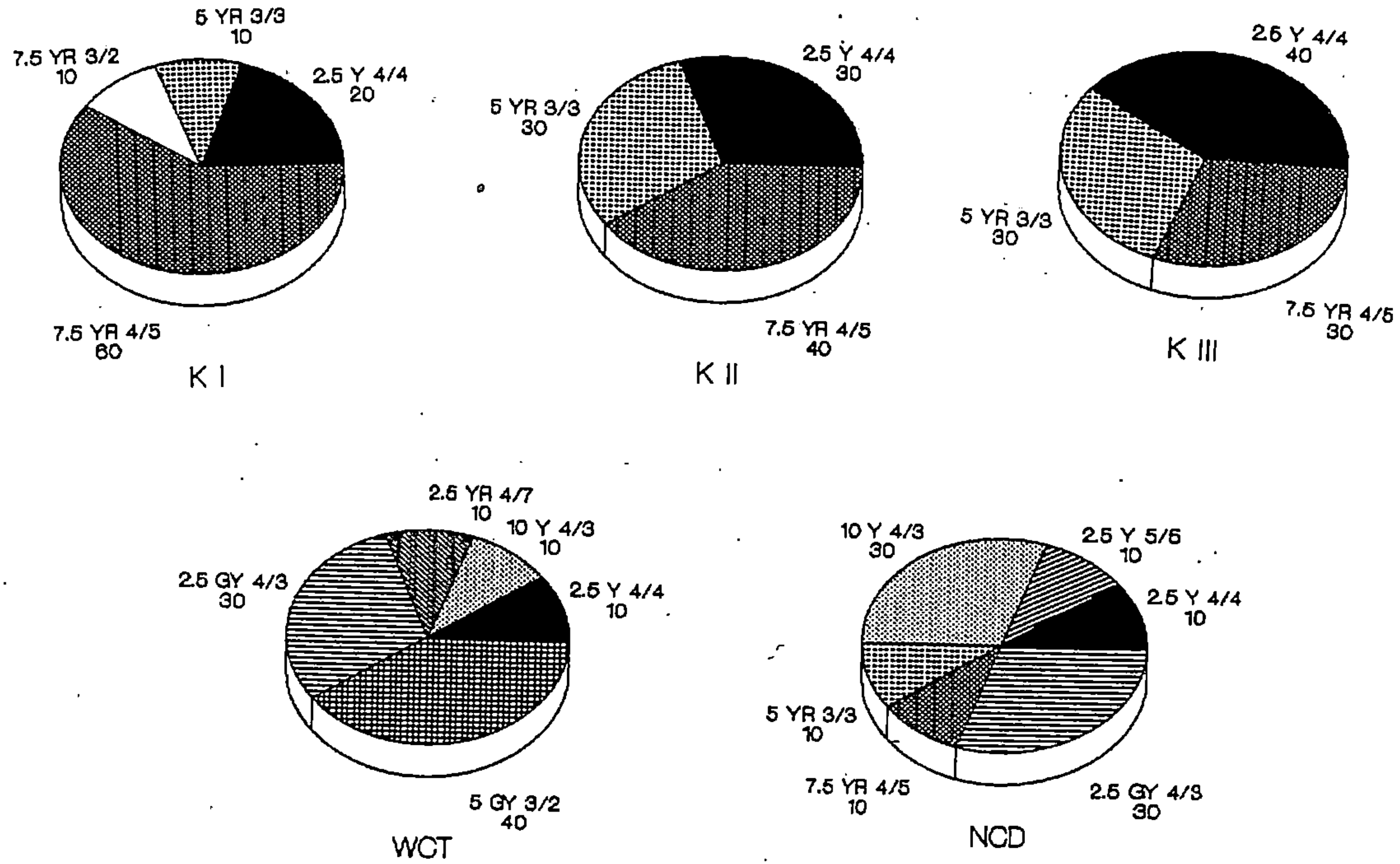


Figure 4

Fig.5. Pigmentation on nut in mother palms

colour index	Colour
2.5 Y 4/4	moderate olive brown
2.5 Y 5/5	light olive brown
10 Y 4/3	moderate brown
2.5 YR 4/3	strong brown
5 YR 3/3	moderate brown
7.5 YR 3/2	greyish brown
7.5 YR 4/5	moderate brown
2.5 GY 4/3	moderate olive green
5 GY 3/2	greyish olive green

Fig.5. Pigmentation on nut in mother palms



the third generation Komadan 60 per cent of the palms had moderate brown nuts, while 40 per cent showed moderate olive brown nuts. Different shades of olive green nuts were noticed in 70 per cent of the WCT palms while the remaining 30 per cent had moderate olive brown, moderate olive and strong brown nuts. In NCD,20 per cent of the palms had olive brown shades, 30 per cent showed olive shade, 20 per cent brown shade and 30 per cent olive green shade nuts.

4.2 Seednut characters

The mean data on 15 seednut characters are given in Table 9. These are represented by bar diagrams in Figure 6. The analysis of variance has shown significant differences for all these characters among the varieties/types.

In polar diameter of nut, the first generation Komadan has shown the maximum value (21.69 cm) followed by KIII(21.48 cm) and NCD (20.15cm) which were all on par. KI, KIII and NCD were superior to WCT for this character, but KII was on par with WCT and NCD.

Table 9. Seednut characters as influenced by the five varieties / types

Variety/ type	Polar diameter of nut (cm)	Equatorial diameter of nut (cm)	Thick-ness of husk (cm)	Wt. of unhusked nut (kg)	Wt. of husked nut (g)	Wt. of opened nut (g)	Volume of nut water (ml)	Thick-ness of meat (cm)	Diameter of eye (cm)	Wt. of embryo (g)	Wt. of shell (g)	Wt. of kernel (g)	Wt. of copra (g)	Oil content (%)	Husk/ nut ratio
KI	21.69	14.89	1.59	1.007	568.30	454.05	114.25	1.24	1.24	0.084	148.18	305.88	179.35	64.98	0.431
KII	19.40	13.79	1.66	1.071	501.05	385.88	115.18	1.22	1.28	0.085	102.30	283.58	158.84	65.38	0.521
KIII	21.48	15.19	2.11	1.227	583.10	449.60	133.50	1.26	1.29	0.082	138.00	314.10	193.70	65.33	0.513
WCT	18.41	12.12	1.93	0.694	276.73	242.35	32.50	1.12	1.01	0.054	81.05	161.30	97.73	65.28	0.588
NCD	20.15	14.69	2.11	0.821	534.60	439.60	96.55	1.07	1.31	0.089	153.05	289.63	182.48	64.03	0.352
$F_{4,45}$	6.55**	5.96**	1.21	7.10**	13.97**	17.27**	6.80**	10.53**	9.23**	14.35**	20.05**	13.62**	13.26**	4.34*	236.51**
S.E	0.542	0.508	0.223	0.079	33.401	21.458	14.988	0.026	0.041	0.004	7.009	16.926	10.516	0.383	0.008
C.D (0.05)	1.545	1.448	—	0.224	95.181	61.148	42.710	0.075	0.116	0.0106	19.972	48.232	29.967	0.786	0.0172

* - Significant at 5 per cent level

** - Significant at 1 per cent level

Fig.6. Seednut characters of the five varieties/types

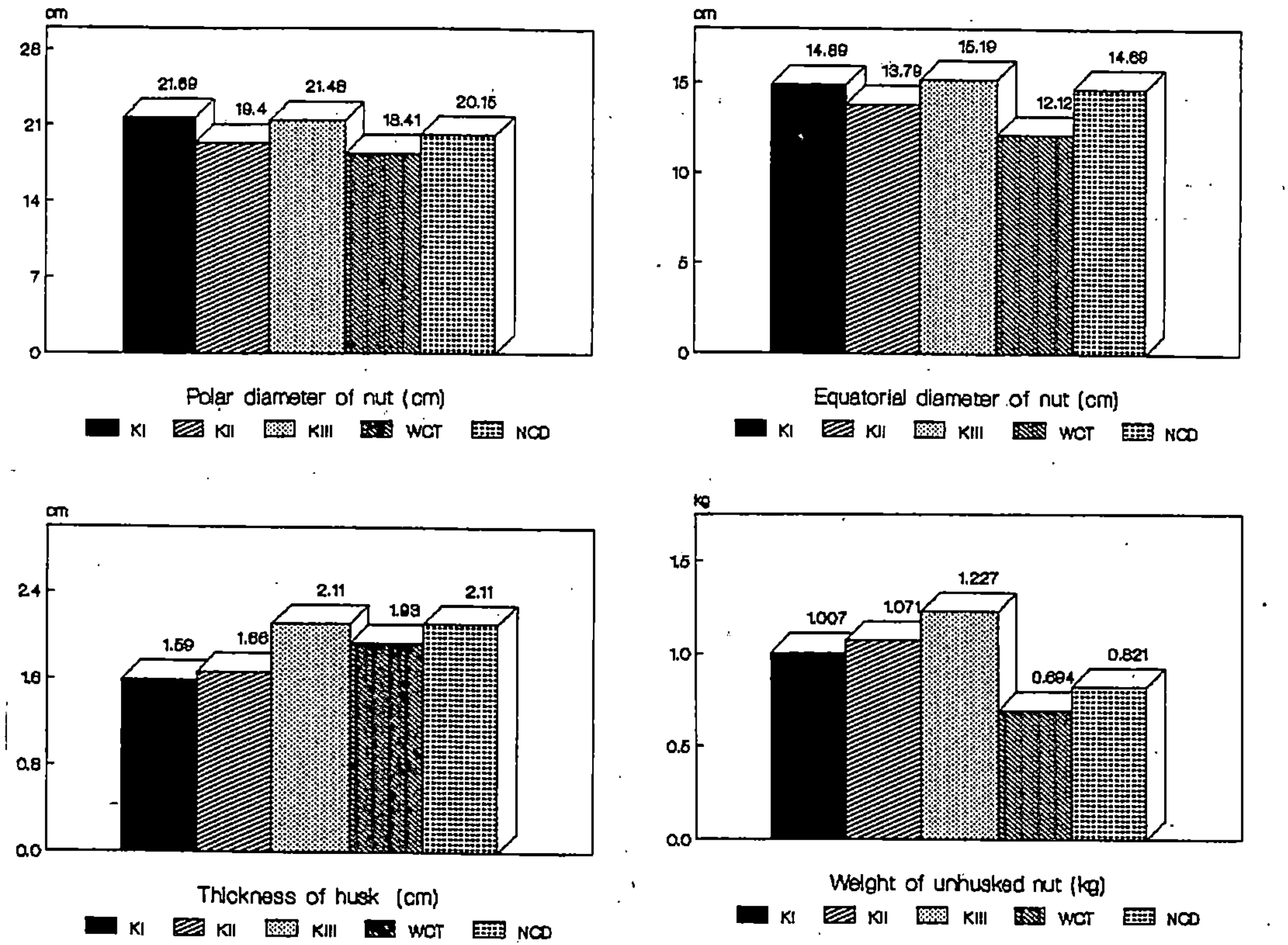


Fig.6. (contd.)

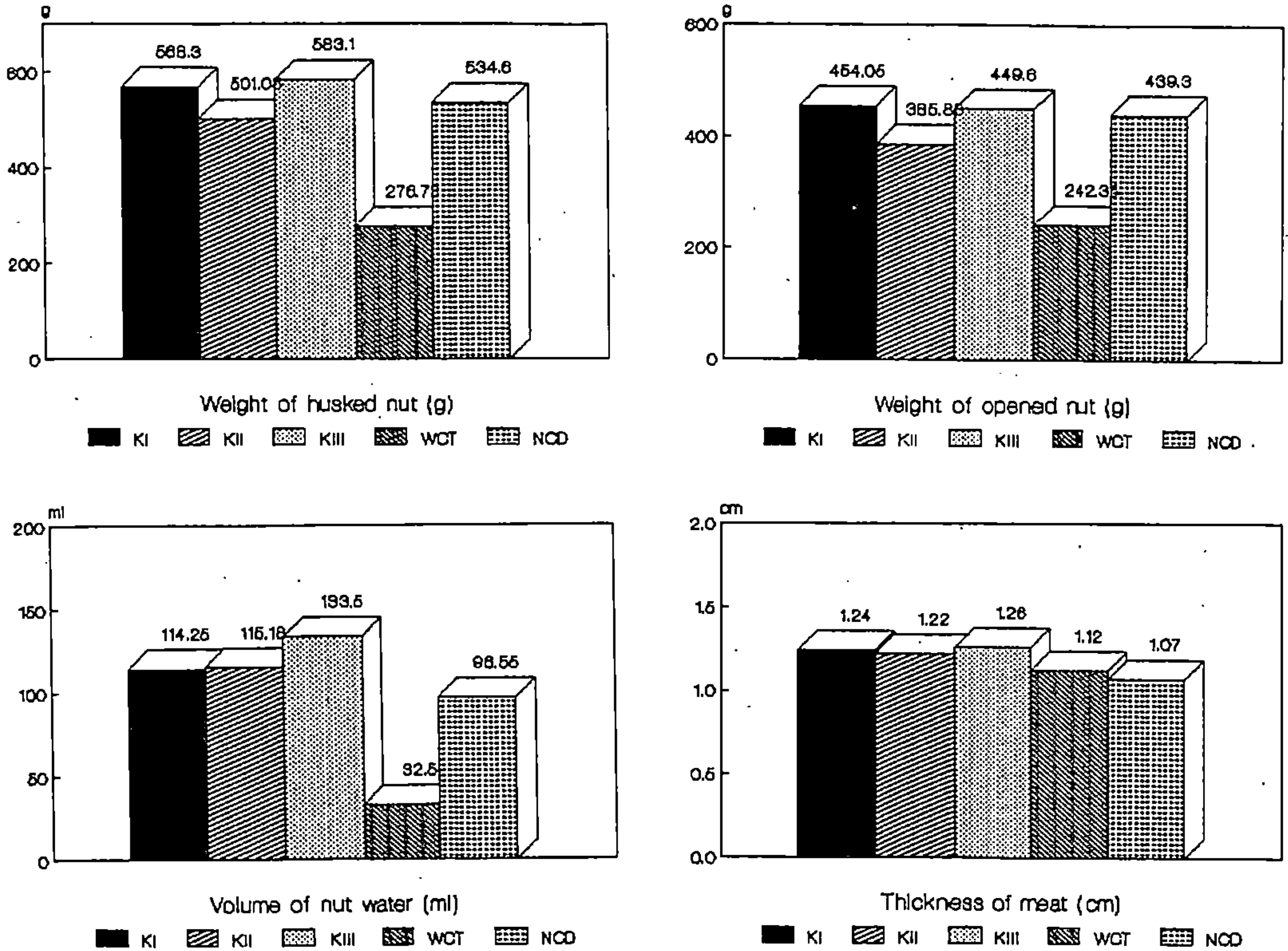
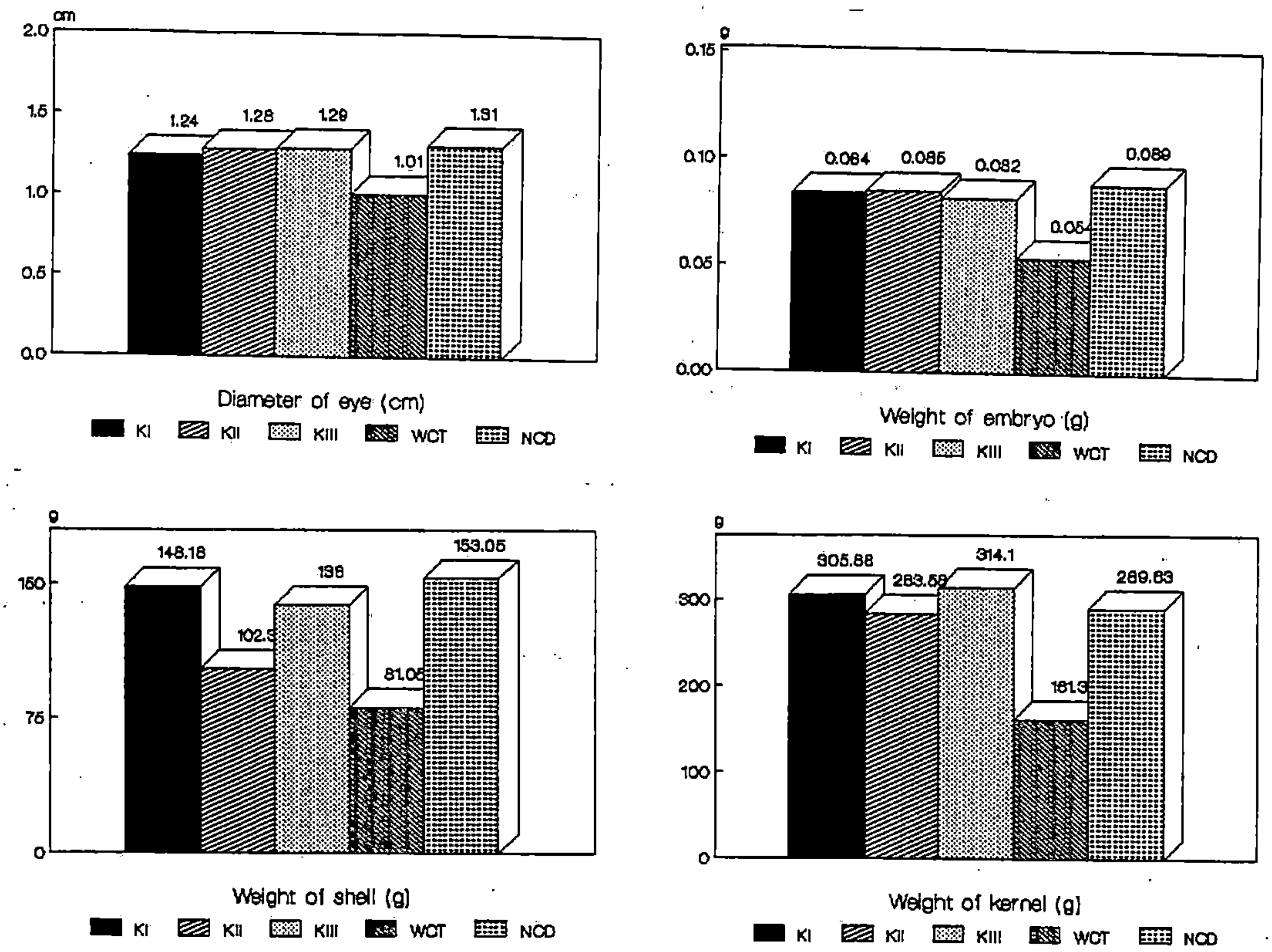
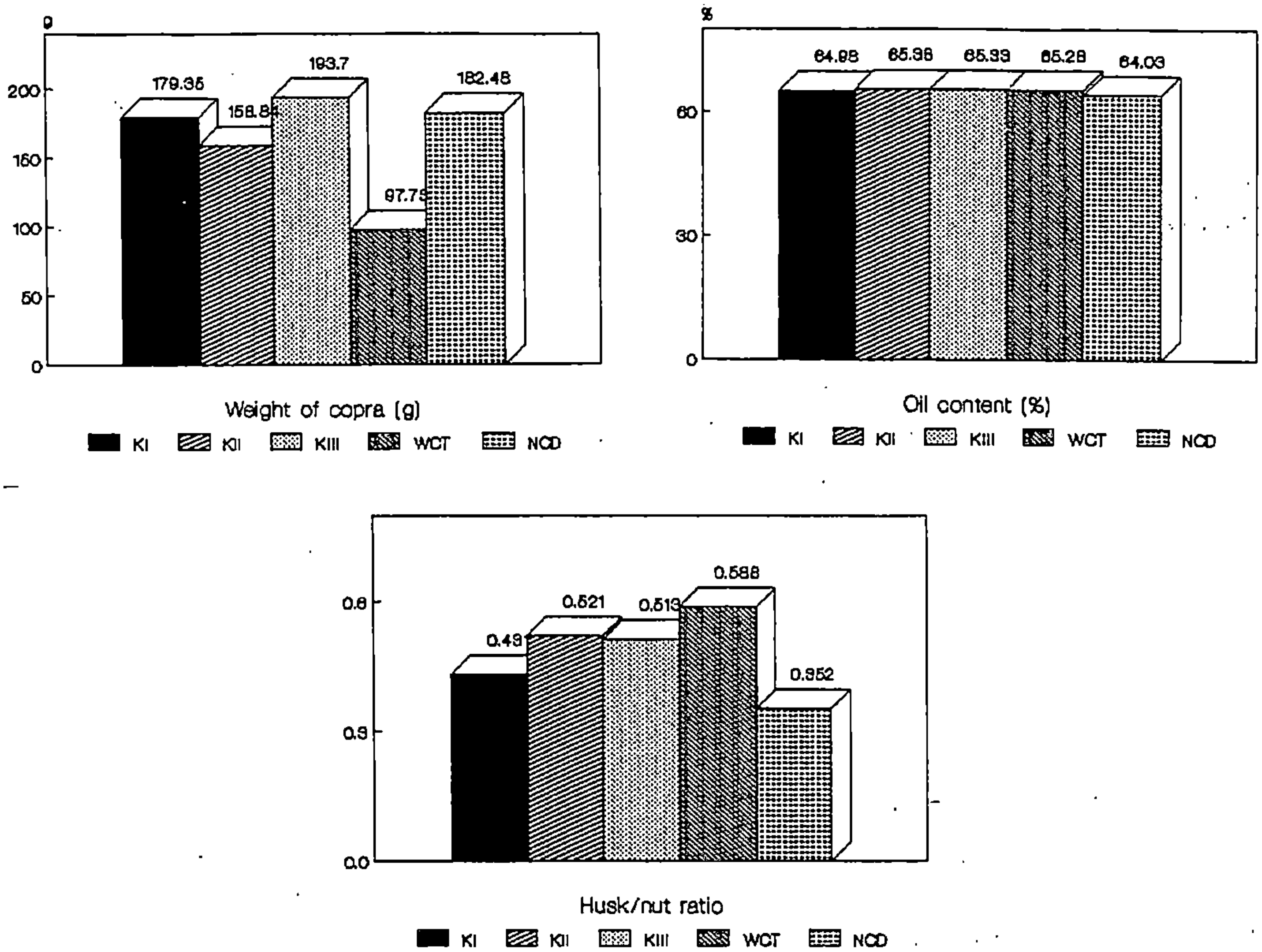

g
566.3
501.05
583.1
276.75
534.6
600
400
200
0
Weight of husked nut (g)
KI KII KIII WCT NCD
g
600
454.05
385.85
449.6
439.3
400
200
0
Weight of opened nut (g)
KI KII KIII WCT NCD
ml
200
150
114.25
133.5
96.55
32.5
100
50
0
Volume of nut water (ml)
KI KII KIII WCT NCD
cm
2.0
1.5
1.24
1.22
1.26
1.12
1.07
1.0
0.5
0.0
Thickness of meat (cm)
KI KII KIII WCT NCD

Fig.6. (contd.)



cm
2.0
1.5
1.0
0.5
0.0
1.24
1.28
1.29
1.01
1.31
Diameter of eye (cm)
KI KII KIII WCT NCD
g
0.15
0.10
0.05
0.00
0.084
0.085
0.082
0.089
Weight of embryo (g)
KI KII KIII WCT NCD
g
150
75
0
148.18
136
153.05
Weight of shell (g)
KI KII KIII WCT NCD
g
300
200
100
0
305.88
314.1
289.63
Weight of kernel (g)
KI KII KIII WCT NCD

Fig.6. (contd.)


g
200
150
100
50
0
179.35
158.84
193.7
97.75
182.48
Weight of copra (g)
KI
KII
KIII
WCT
NCD
%
60
30
0
64.98
65.38
65.33
65.28
64.03
Oil content (%)
KI
KII
KIII
WCT
NCD
0.6
0.3
0.0
0.43
0.521
0.513
0.588
0.352
Husk/nut ratio
KI
KII
KIII
WCT
NCD

No significant difference in the equatorial diameter of nut was observed in the three generations of Komadan and NCD but it was significantly low in WCT (12.12cm).

In thickness of husk, there was no significant difference among the varieties/types.

In weight of unhusked nut, the three generations of Komadan were found significantly superior to WCT with KIII showing the maximum value (1.227 kg). The first generation Komadan was found to be on par with NCD for this character. WCT and NCD were on par and significantly inferior only to KII and KIII (Fig.7).

The three generations of Komadan and NCD were on par and significantly superior to WCT for weight of husked nut with KIII showing the maximum value (583.10g) followed by KI (568.30g), NCD (534.60g)and KII (501.05g). The lowest weight was shown by WCT (276.73g) (Fig.8).

In weight of opened nut, the first and third generations of Komadan (454.05g and 449.60g respectively)

Fig.7. Unhusked nuts of the five varieties/types

No.	variety/type
1.	KI
2.	KII
3.	KIII
4.	WCT
5.	NCD

Fig.8. Husked nuts of the five varieties/types

No	Variety/type
1.	KI
2.	KII
3.	KIII
4.	WCT
5.	NCD

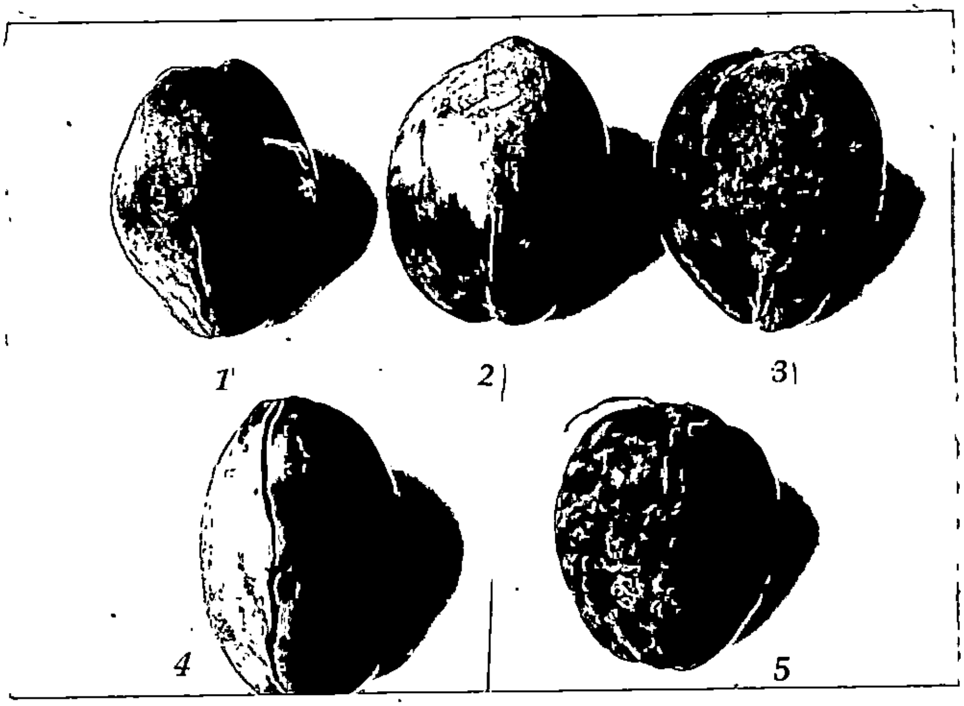


Figure 7

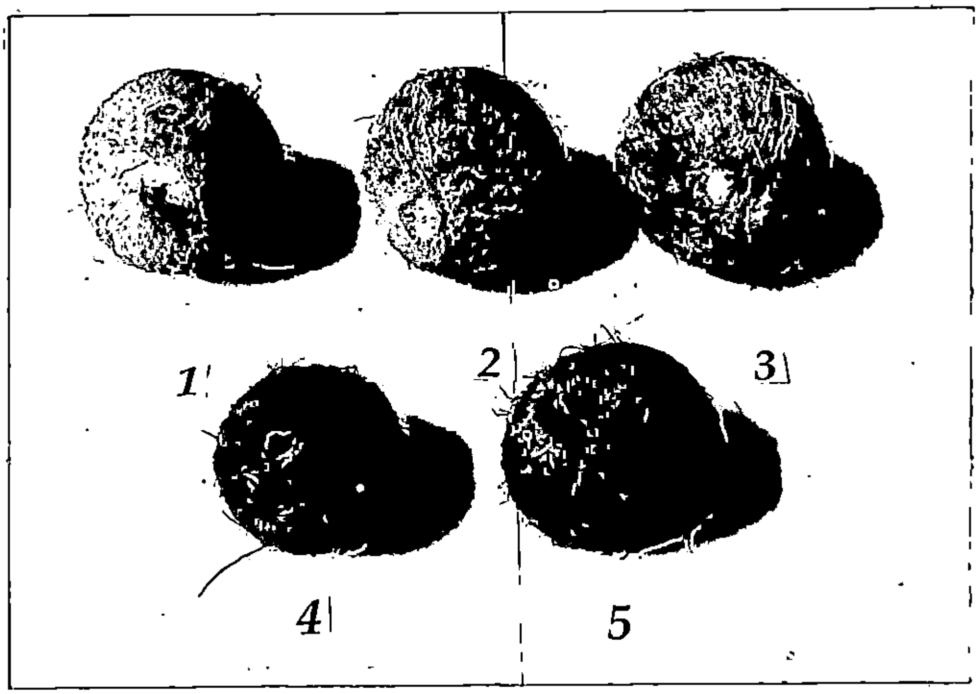


Figure 8

followed by NCD (439.30g) were on par and significantly superior to WCT. However KII(385.88g) was found to be on par with NCD.

In volume of nut water, the three generations of Komadan followed by NCD were sharing on par relation, with KIII expressing the maximum value (133.50ml) They were significantly superior to WCT in this character also.

In thickness of meat, the Komadan group has behaved as a distinct variety with insignificant intragroup difference and significant superiority over both WCT and NCD where the latter two were on par. The maximum value of 1.26 cm was exhibited by KIII followed by KI (1.24 cm) and KII (1.22cm)(Fig.9-a to e).

The three Komadan generations together with NCD gave significantly superior values for diameter of eye over WCT. The maximum value of 1.31 cm was expressed by NCD followed by KIII (1.29cm), KII(1.28cm) and KI (1.24cm) which were on par. Very similar trend was noticed for weight of embryo (Fig.10) and weight of kernel.

In weight of shell, the three Komadan groups and NCD were showing significantly superior values over WCT. The

Fig.9 - a. Opened nut showing thickness of meat in KI

Fig. 9 - b. Opened nut showing thickness of meat in KII

Fig. 9 - c. Opened nut showing thickness of meat in KIII

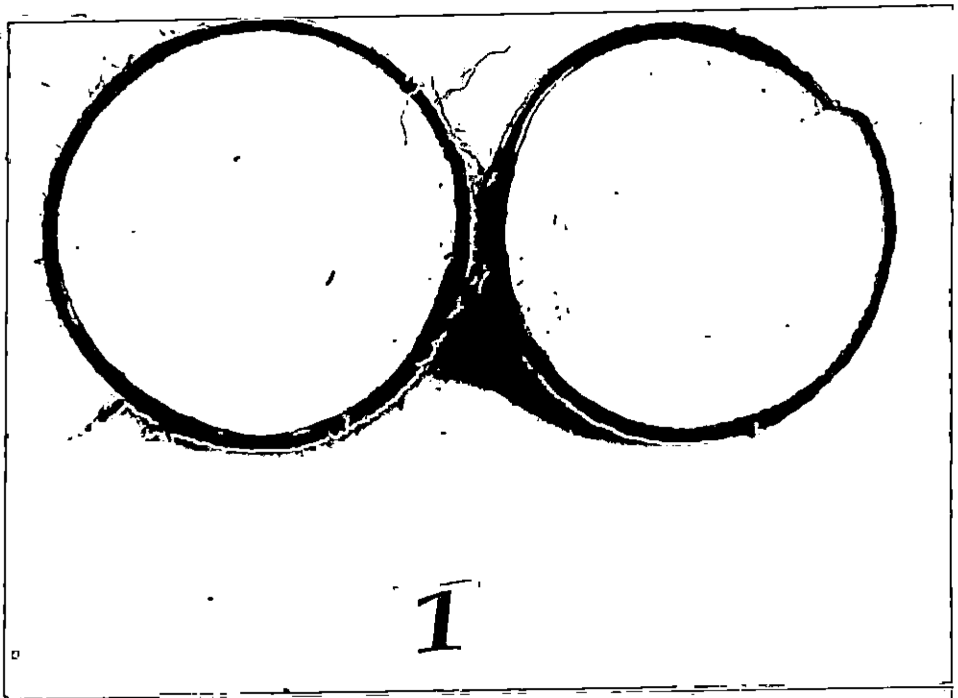


Figure 9-a

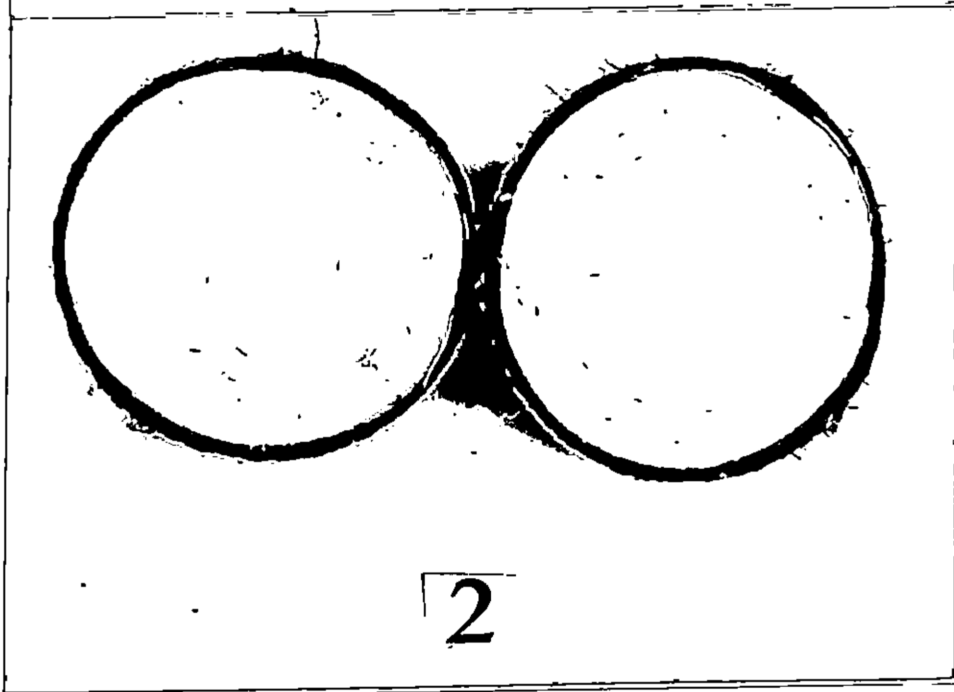


Figure 9-b

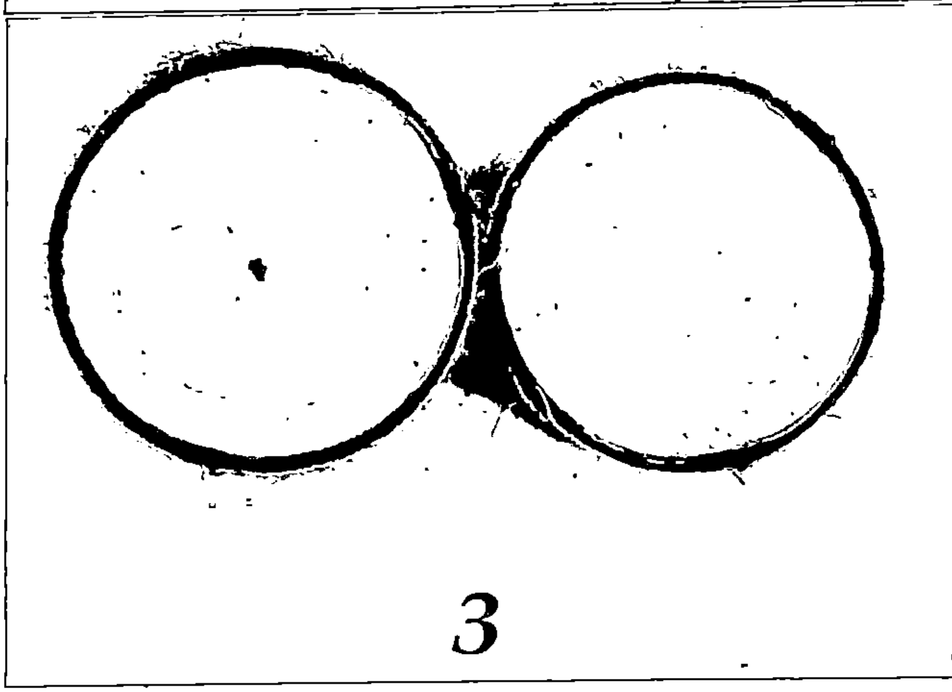


Figure 9-c

Fig. 9 - d. Opened nut showing thickness of meat in WCT

Fig. 9 - e. Opened nut showing thickness of meat in NCD

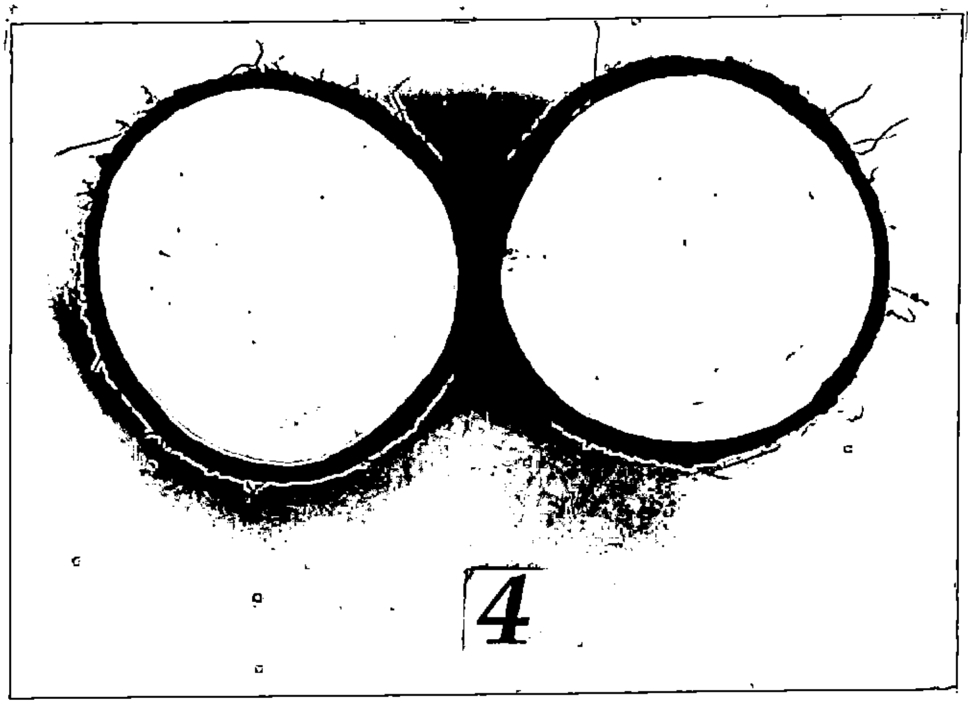


Figure 9-d

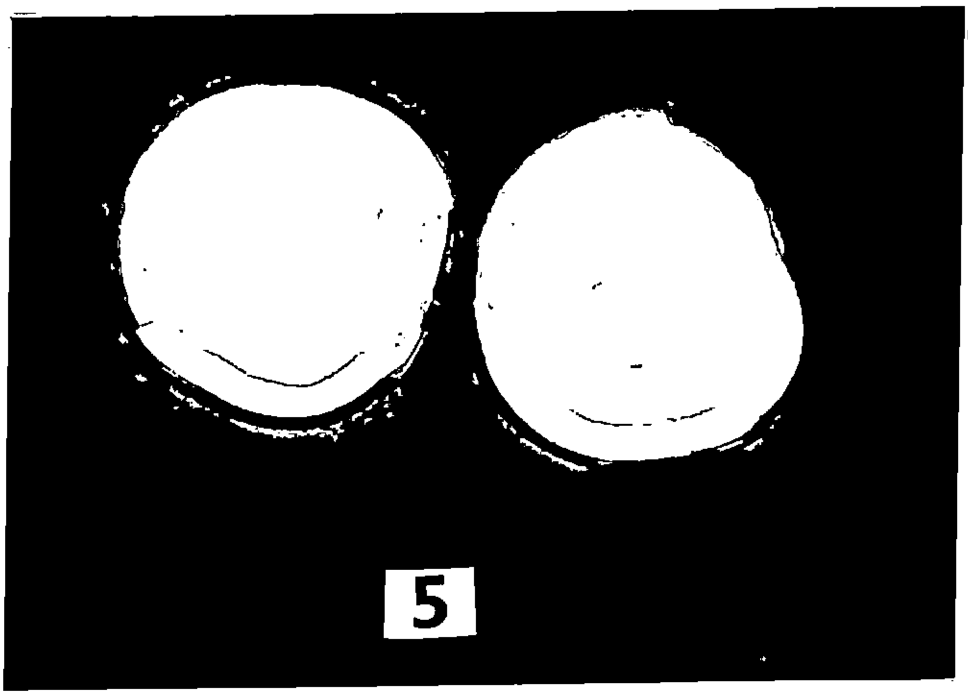


Figure 9-e

Fig.10. Embryos of open pollinated nuts of the five varieties/types

No.	Variety/type
1.	KI
2.	KII
3.	KIII
4.	WCT
5.	NCD

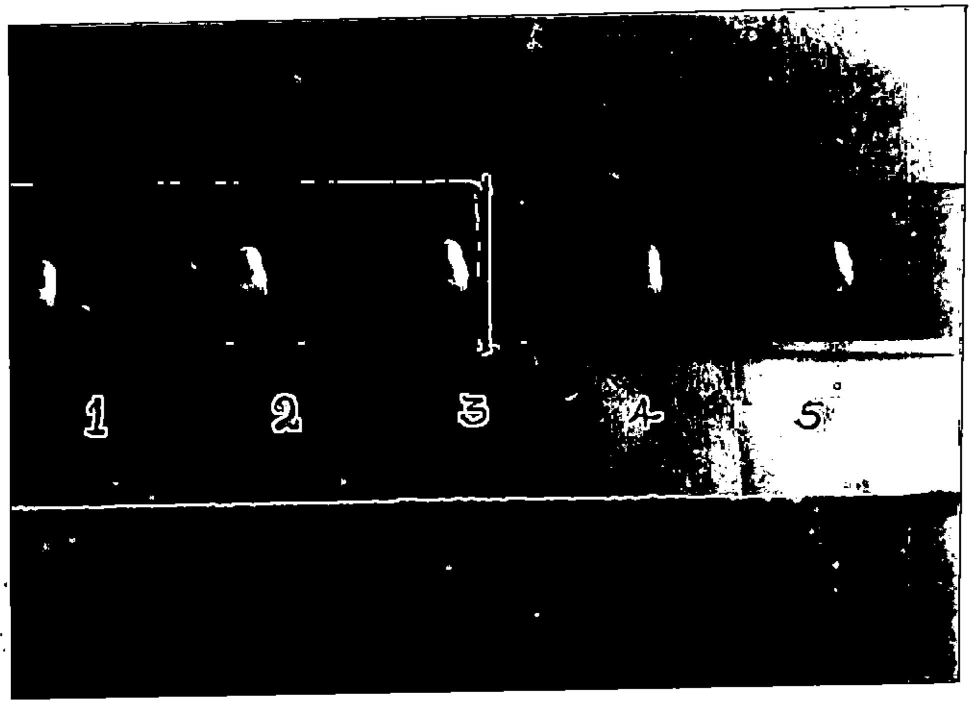


Figure 10

maximum value was expressed by NCD (153.05g) followed by KI (148.18g) and KIII (138.00g). In this character KII (102.30g) was found significantly inferior to both KI and KIII as well as NCD.

In weight of copra,all the three groups of Komadan and NCD were found significantly superior to WCT. Maximum value for this character was expressed by KIII (193.70g) followed by NCD (182.48 g) and KI (179.35 g). The copra weight of KII (158.84 g) was found significantly inferior to KIII but on par with KI and NCD.

In percentage of oil content, the three Komadan groups and WCT were found to be on par and significantly superior to NCD. The maximum value was shown by KII (65.38 per cent) followed by KIII (65.33 per cent), WCT (65.28 per cent) and KI (64.98 per cent).

The lowest husk/nut ratio was expressed by NCD (0.352) which was significantly lower to all other varieties/types. Among the Komadan groups, KI was showing the lowest value (0.431). The maximum value for this character was expressed by WCT (0.588) followed by KII (0.521) and KIII (0.513) where WCT showed significant difference compared to the two Komadan generations which were on par.

In Figure 11 , the individual mother palms belonging to each of the five different varieties /types were plotted in a scatter diagram against the two seednut characters namely weight of unhusked nut and percentage of husk, to locate the ancestral position of the Komadan groups according to the Niu kafa-Niu vai Introgression hypothesis proposed by Harries (1982). In this diagram WCT palms were found locating themselves towards the Niu kafa region and NCD towards the Niu vai region. The three Komadan groups were found in between these two regions with the first generation more towards NCD and the second and third generations more towards WCT with progressive increase in both nut weight and the percentage of husk.

4.2.1 Genetic parameters of seednut characters

The phenotypic and genotypic coefficients of variation, heritability and genetic advance for 15 seednut characters were estimated and presented in Table 10 (Fig.12).

Fig.11. Percentage of husk to weight of unhusked nut

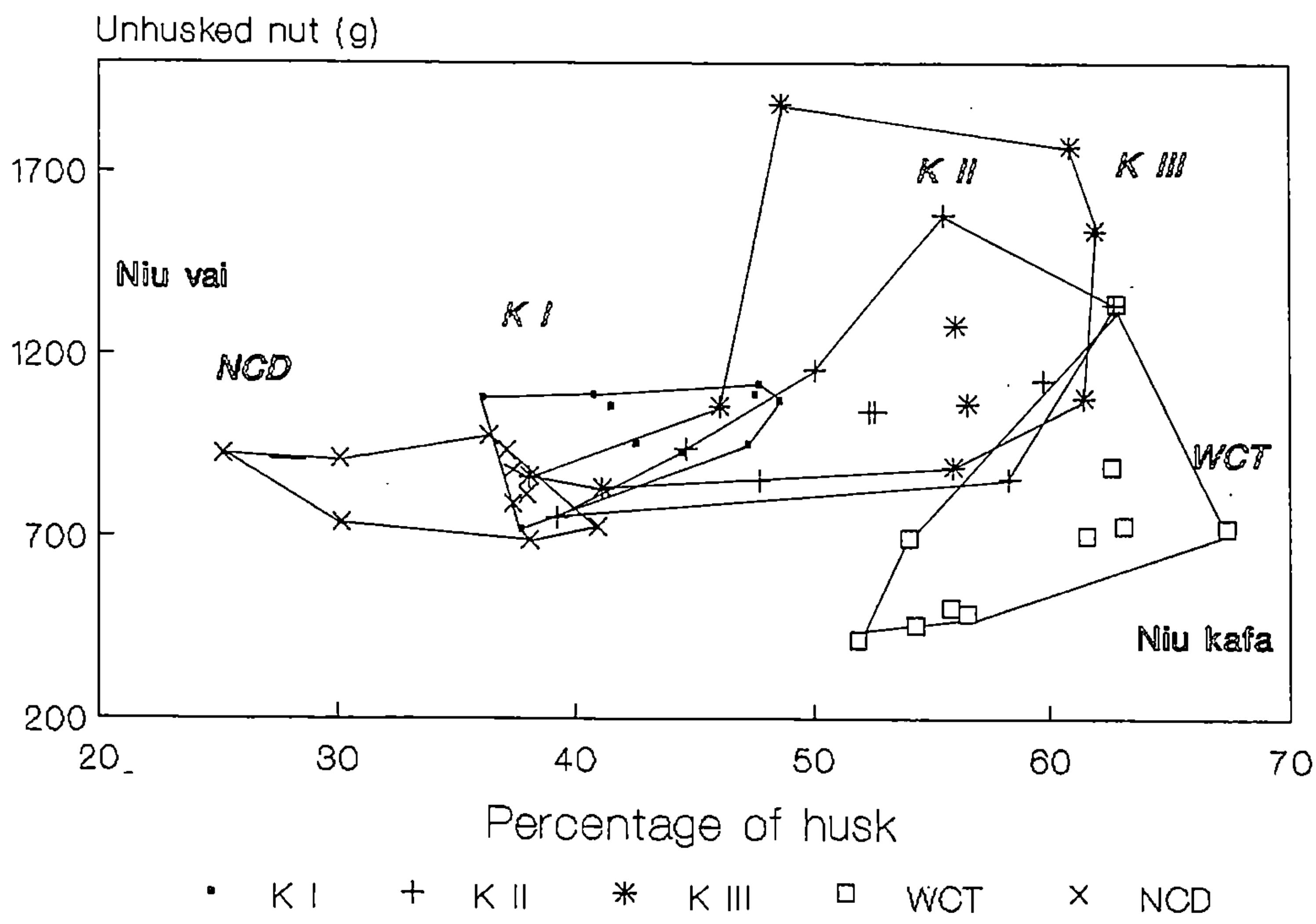


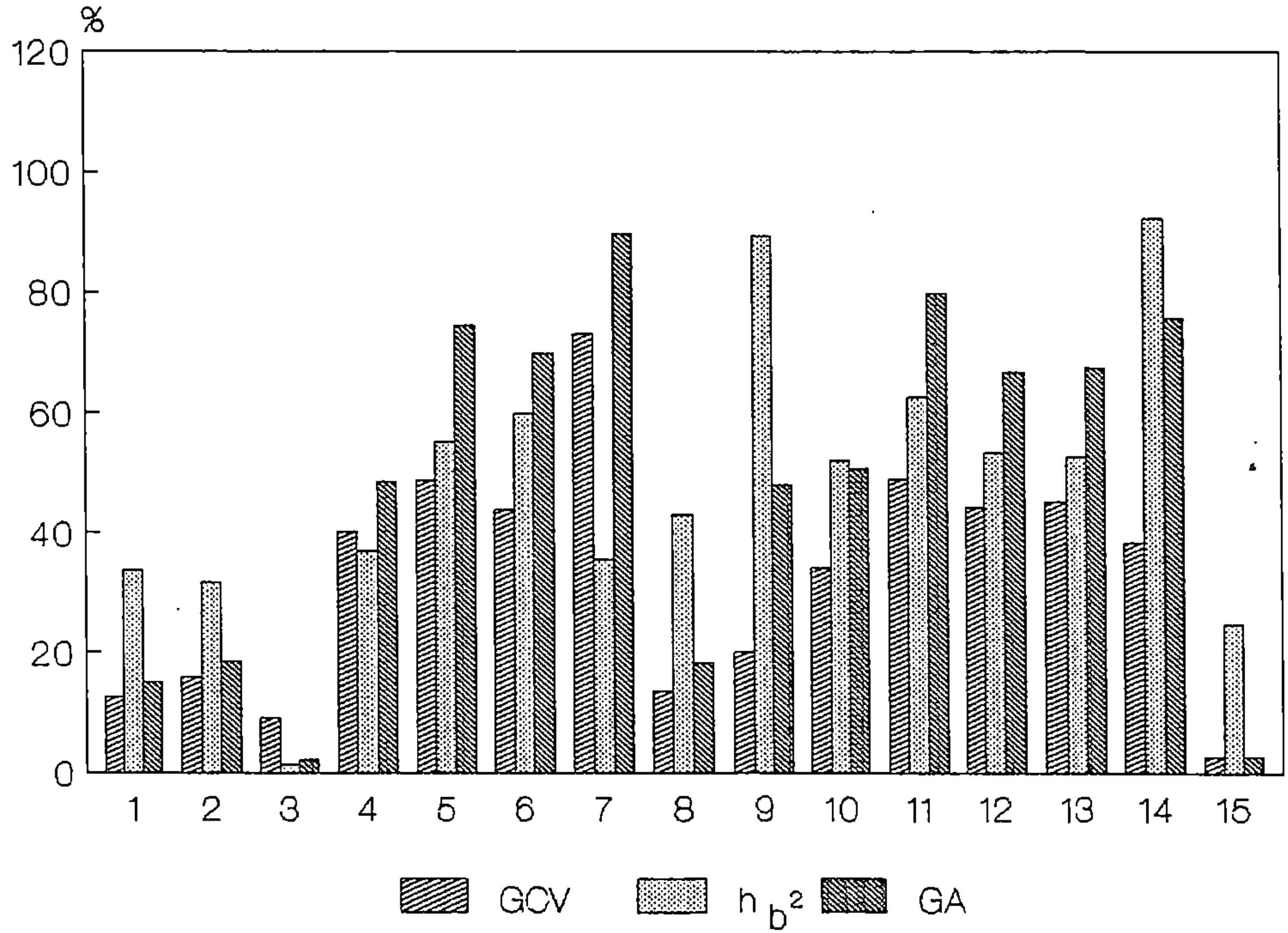
Table 10. Genetic parameters of seednut characters

Sl. No.	Character	Phenotypic coefficient of variation (%)	Genotypic coefficient of variation (%)	Heritability (%)	Genetic advance (% of mean)
1.	Polar diameter of nut	21.62	12.55	33.68	15.00
2.	Equatorial diameter of nut	28.29	15.94	31.73	18.49
3.	Thickness of husk	78.16	9.15	1.37	2.20
4.	Weight of unhusked nut	66.05	40.15	36.95	48.46
5.	Weight of husked nut	65.65	48.73	55.09	74.51
6.	Weight of opened nut	56.61	43.80	59.86	69.81
7.	Volume of nut water	122.63	73.09	35.52	89.73
8.	Thickness of meat	20.62	13.52	42.98	18.26
9.	Diameter of eye	21.22	20.06	89.33	48.03
10.	Weight of embryo	47.35	34.16	52.05	50.77
11.	Weight of shell	61.86	48.96	62.64	79.82
12.	Weight of kernel	60.57	44.23	53.33	66.76
13.	Weight of copra	62.28	45.16	52.59	67.47
14.	Husk / nut ratio	39.96	38.41	92.39	75.73
15.	Oil content	5.37	2.67	24.67	2.73

Fig. 12. Genetic parameters of seednut characters.

No.	Character
1.	Polar diameter of nut
2.	Equatorial diameter of nut
3.	Thickness of husk
4.	Weight of unhusked nut
5.	Weight of husked nut
6.	Weight of opened nut
7.	Volume of nut water
8.	Thickness of meat
9.	Diameter of eye
10.	Weight of embryo
11.	Weight of shell
12.	Weight of kernel
13.	Weight of copra
14.	Husk / nut ratio
15.	Oil content

Fig.12. Genetic parameters of seednut characters



Volume of nut water showed the highest phenotypic as well as genotypic coefficients of variation (122.63 per cent and 73.09 per cent respectively). Moderate to high phenotypic and moderate genotypic coefficients of variation were noticed for weight of unhusked nut , weight of husked nut, weight of shell, weight of kernel and weight of copra. Thickness of husk showed high phenotypic coefficient of variation (78.16 per cent) but the genotypic coefficient of variation was low (9.15 per cent). The lowest values for phenotypic and genotypic coefficients of variation were recorded for oil content.

Husk/nut ratio showed the maximum heritability (92.39 per cent) and high genetic advance(75.73 per cent). High heritability and genetic advance were shown for weight of husked nut, weight of opened nut, weight of embryo, weight of shell, weight of kernel and weight of copra. Diameter of eye showed very high heritability (89.33 per cent) but the genetic advance for this character was low (48.03 per cent). Volume of nut water exhibited low heritability (35.52 per cent) but had a genetic advance of 89.73 per cent, the highest value recorded among all the characters. Heritability and genetic advance were lowest for thickness of husk (1.37 per cent and 2.20 per cent respectively) the next highest being recorded for oil content.

4.2.2 Correlations among seednut characters

Correlations among the seednut characters of the five varieties/types are presented in Tables 11 to 15.

In first generation Komadan, the weight of unhusked nut was found significantly and positively correlated with all other characters except oil content, thickness of husk and thickness of meat. The weight of husked and opened nuts were significantly and positively correlated with all characters except thickness of husk, thickness of meat and husk/nut ratio while it was negatively correlated with oil content. The weight of kernel was found to be significantly and positively correlated with all other characters except thickness of husk, volume of nut water, thickness of meat and husk/nut ratio and negatively correlated with oil content. The weight of copra was also seen positively correlated with all other characters except oil content, thickness of husk and husk/nut ratio.

Table 11 - Correlation among seednut chraracters in KI

Character	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13	x14	x15
x1. Oil content	----														
x2. Polar diameter	0.0245	----													
x3. Equatorial diameter	0.0906	0.3090	----												
x4. Thickness of husk	-0.0768	-0.1146	0.1169	----											
x5. Wt. of unhusked nut	-0.0906	0.3583*	0.4489**	-0.1740	----										
x6. Wt. of husked nut	-0.3547*	0.4091**	0.4036**	0.0392	0.7791**	----									
x7. Wt. of opened nut	-0.3987*	0.3701*	0.3781*	-0.0669	0.6852**	0.9160**	----								
x8. Volume of nut water	-0.1459	0.3155*	0.2899	0.1982	0.6332**	0.7527**	0.4253**	----							
x9. Thickness of meat	0.1342	0.2216	0.2453	-0.1814	0.2855	0.2335	0.2483	0.1193	----						
x10. Diameter of eye	0.1124	0.2339	0.4366**	0.0439	0.7900**	0.5544**	0.3804*	0.6264**	0.1792	----					
x11. Wt. of embryo	-0.2221	0.3275*	0.0825	0.1881	0.4055**	0.5799**	0.5256**	0.4456**	0.1347	0.2215	----				
x12. Wt. of shell	-0.3402*	0.0677	0.0934	0.0833	0.4970**	0.7075**	0.6893**	0.4649**	0.0923	0.2154	0.5331**	----			
x13. Wt. of kernel	-0.3346*	0.4406**	0.4375**	-0.1298	0.6208**	0.8073**	0.9250**	0.3033	0.2710	0.3764*	0.3965*	0.3623*	----		
x14. Wt. of copra	-0.2032	0.5470**	0.5412**	-0.0616	0.6548**	0.7728**	0.8334**	0.3757*	0.4234**	0.4362**	0.3200*	0.4531**	0.8346**	----	
x15. Husk / nut ratio	0.3702*	0.0177	0.1945	-0.3181	0.4948**	-0.1530	-0.1929	-0.0285	0.1649	0.4841**	-0.1932	-0.2192	-0.1332	-0.0129	----

In second generation Komadan,polar diameter of nut was significantly and positively correlated with all characters except oil content, thickness of meat, diameter of eye and weight of embryo. Equatorial diameter of nut was positively correlated with all characters except oil content and diameter of eye. Weight of unhusked nut was positively correlated with all characters except oil content, thickness of meat and diameter of eye. Weight of husked and opened nuts were found to be significantly and positively correlated with all characters including between themselves except oil content, diameter of eye and husk/nut ratio. However, weight of opened nut was positively correlated with oil content. Except for four characters viz., oil content, thickness of meat, diameter of eye and husk/nut ratio, weight of shell was positively correlated with all characters. The weight of kernel and copra were significantly and positively correlated with all characters and between themselves except oil content, thickness of husk, diameter of eye, weight of embryo and husk/nut ratio.

In third generation Komadan,equatorial diameter of nut was significantly and positively correlated with all characters except oil content, weight of shell and husk/nut ratio. Weight of unhusked, husked and opened nut showed

Table 12. Correlation among seednut characters in KII

Character	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13	x14	x15
x1. Oil content	----														
x2. Polar diameter	0.1632	----													
x3. Equatorial diameter	0.0326	0.7847**	---												
x4. Thickness of husk	0.0393	0.4168**	0.5912**	----											
x5. Wt. of unhusked nut	0.1505	0.7749**	0.8062**	0.5404**	----										
x6. Wt. of husked nut	0.2557	0.5067**	0.6061**	0.3487*	0.7416**	----									
x7. Wt. of opened nut	0.3190*	0.5968**	0.6650**	0.3455*	0.7235**	0.9460**	----								
x8. Volume of nut water	0.1412	0.3228*	0.4455**	0.3015	0.6549**	0.9190**	0.7416**	----							
x9. Thickness of meat	0.0459	0.2918	0.3251*	0.2400	0.2728	0.3190*	0.3223*	0.2683	----						
x10. Diameter of eye	0.0324	0.1810	0.0676	0.0286	-0.0067	0.0391	0.0088	0.0702	0.5733**	----					
x11. Wt. of embryo	0.0593	0.1918	0.3359*	0.4221**	0.4521**	0.4973**	0.4199**	0.5185**	-0.1484	-0.3481	----				
x12. Wt. of shell	0.2564	0.5590**	0.7050**	0.3866*	0.7188**	0.8334**	0.8388**	0.7047**	0.2201	-0.1001	0.5804**	----			
x13. Wt. of kernel	0.2963	0.4911**	0.4816**	0.2341	0.5625**	0.8203**	0.9009**	0.6021**	0.3304*	0.0936	0.1964	0.5192**	----		
x14. Wt. of copra	0.1304	0.4926**	0.4446**	0.1137	0.4204**	0.6405**	0.7349**	0.4317**	0.4044**	0.2392	-0.0173	0.4145**	0.8230**	----	
x15. Husk / nut ratio	-0.0636	0.5226**	0.4578**	0.4041**	0.5990**	-0.0734	-0.0687	-0.0687	-0.0309	-0.0665	0.1334	0.0862	-0.1766	-0.1842	----

Table 13. Correlation among seednut characters in K III

Character	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13	x14	x15
x1. Oil content	----														
x2. Polar diameter	-0.0854	----													
x3. Equatorial diameter	0.1350	0.5162**	----												
x4. Thickness of husk	-0.0695	0.2457	0.5349**	---											
x5. Wt. of unhusked nut	-0.0169	0.3874*	0.6475**	0.2993	----										
x6. Wt. of husked nut	0.2182	0.0751	0.6573**	0.3080	0.8314**	----									
x7. Wt. of opened nut	0.2414	0.0629	0.6304**	0.3645*	0.7406**	0.9460**	----								
x8. Volume of nut water	0.1562	0.0789	0.5911**	0.1911	0.8181**	0.9154**	0.7355**	----							
x9. Thicknes of meat	0.3914*	0.2872	0.5654**	0.2550	0.3695*	0.5053**	0.6046**	0.3053*	----						
x10. Diameter of eye	0.2800	0.3316*	0.7106**	0.3611*	0.5152**	0.5948**	0.6697**	0.4116**	0.6488**	----					
x11. Wt. of embryo	0.0895	0.1017	0.3728*	0.2923	0.4939**	0.5464**	0.6038**	0.3921*	0.2602	0.4231**	----				
x12. Wt. of shell	-0.1838	0.1618	0.2945	0.4288**	0.5919**	0.5426**	0.5318**	0.4737**	0.1981	0.1427	0.2088	----			
x13. Wt. of kernel	0.3574*	0.0150	0.5866**	0.2952	0.6239**	0.8802**	0.9580**	0.6501**	0.6490**	0.6874**	0.6099**	0.3240*	----		
x14. Wt. of copra	0.3682*	0.0145	0.5299**	0.2110	0.3314*	0.6817**	0.8008**	0.4305**	0.7249**	0.6494**	0.3535*	0.2207	0.8581**	----	
x15. Husk / nut ratio	-0.3130	0.4825**	0.0775	-0.0393	0.4904**	0.0504	-0.1584	0.0914	-0.1567	0.0084	0.0452	0.1325	-0.2472	-0.4878	----

positive correlation with all characters and among themselves except oil content and thickness of husk in the case of unhusked nut ; oil content, polar diameter of nut, thickness of husk and husk/nut ratio in the case of husked and opened nuts. However opened nut showed positive correlation with thickness of husk. Diameter of eye exhibited significant positive correlation with all characters except oil content, weight of shell and husk/nut ratio. Weight of kernel and copra showed positive correlation with all characters and among themselves except polar diameter, thickness of husk, weight of shell (correlated with weight of kernel) and husk/nut ratio.

In the variety WCT, polar diameter of nut was found to be significantly and positively correlated with all characters except oil content, thickness of husk, thickness of meat and husk/nut ratio. The equatorial diameter of nut showed significant positive correlation with all characters except oil content and thickness of meat. Weight of husked and opened nut, volume of nut water and diameter of eye showed significant positive correlation with all characters and among themselves except oil content, thickness of meat and husk/nut ratio. Weight of unhusked nut and weight of shell were found to be significantly

Table 14. Correlation among seednut characters in WCT

Character	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13	x14	x15
x1. Oil content	----														
x2. Polar diameter	-0.1719	----													
x3. Equatorial diameter	0.0136	0.5458**	----												
x4. Thickness of husk	0.1415	0.2572	0.7007**	----											
x5. Wt. of unhusked nut	0.1788	0.4182**	0.8700**	0.7451**	----										
x6. Wt. of husked nut	0.1301	0.5205**	0.8731**	0.6480**	0.9380**	----									
x7. Wt. of opened nut	0.1435	0.5217**	0.8663**	0.6618**	0.9337**	0.9865**	----								
x8. Volume of nut water	0.0780	0.4640**	0.7824**	0.5857**	0.8740**	0.9428**	0.9000**	----							
x9. Thicknes of meat	-0.0908	0.0903	0.1303	0.0215	-0.0411	0.1376	0.0956	0.2342	----						
x10. Diameter of eye	0.1196	0.4381**	0.7160**	0.5829**	0.7457**	0.7803**	0.7951**	0.7345**	-0.0555	----					
x11. Wt. of embryo	0.3064	0.3591*	0.6219**	0.5284**	0.7019**	0.7189**	0.7370**	0.6541**	0.0618	0.7629**	----				
x12. Wt. of shell	0.3112	0.3789*	0.7388**	0.6236**	0.8737**	0.8993**	0.9169**	0.8001**	0.0531	0.7331**	0.7339**	----			
x13. Wt. of kernel	0.0676	0.5549**	0.8751**	0.6524**	0.9136**	0.9762**	0.9867**	0.8984**	0.1044	0.7868**	0.6995**	0.8425**	----		
x14. Wt. of copra	-0.0407	0.5874**	0.8109**	0.4784**	0.7212**	0.8639**	0.8693**	0.7808**	0.2302	0.6553**	0.5551**	0.7660**	0.8686**	----	
x15. Husk / nut ratio	0.1056	-0.0593	0.3850*	0.5820**	0.5708**	0.2775	0.3016	0.2040	-0.4669**	0.2492	0.2544	0.3561*	0.2622	0.0798	----

and positively correlated with all characters and among themselves except oil content and thickness of meat. Weight of kernel and copra have shown significant positive correlation with all characters and among themselves except oil content, thickness of meat, husk/nut ratio and weight of embryo (correlated with weight of copra).

In NCD, equatorial diameter of nut was found to be significantly and positively correlated with all characters except polar diameter, thickness of meat, weight of embryo and was negatively correlated with husk/nut ratio. Weight of unhusked, husked and opened nuts were significantly and positively correlated with all characters and among themselves except oil content, polar diameter (correlated with weight of husked nut), thickness of husk and thickness of meat. The three characters viz., weight of unhusked, husked and opened nuts showed significant negative correlation with husk/nut ratio. The weight of husked nut also showed negative correlation with polar diameter. Diameter of eye was found to be significantly and positively correlated with all characters except oil content, polar diameter, thickness of meat and husk/nut ratio. Weight of

Table 15. Correlation among seednut characters in NCD

Character	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13	x14	x15
x1. Oil content	----														
x2. Polar diameter	0.3823*	----													
x3. Equatorial diameter	0.3460*	-0.0732	----												
x4. Thickness of husk	0.2798	0.3100	0.3705*	----											
x5. Wt. of unhusked nut	0.1664	-0.1539	0.6619**	0.0476	----										
x6. Wt. of husked nut	0.1411	-0.3632*	0.6762**	0.0786	0.9013**	----									
x7. Wt. of opened nut	0.2352	-0.2725	0.6803**	0.1246	0.7917**	0.9179**	----								
x8. Volume of nut water	-0.0622	-0.3073	0.3661*	-0.0352	0.7108**	0.6999**	0.3662*	----							
x9. Thicknes of meat	0.3788*	0.4244**	0.1430	0.3583*	0.0789	-0.0338	0.0251	-0.1142	----						
x10. Diameter of eye	0.2598	0.0093	0.5672**	0.4044**	0.6280**	0.6226**	0.6066**	0.3791*	0.3012	----					
x11. Wt. of embryo	0.0955	-0.2157	0.2455	-0.1678	0.5383**	0.5686**	0.5519**	0.3519*	0.0310	0.3975*	----				
x12. Wt. of shell	0.2942	-0.1378	0.5720**	0.2365	0.5317**	0.6630**	0.7327**	0.2545	-0.1171	0.3733*	0.4276**	----			
x13. Wt. of kernel	0.2025	-0.2642	0.6441**	0.0492	0.7666**	0.8625**	0.9381**	0.3425*	0.1228	0.6073**	0.5084**	0.4795**	----		
x14. Wt. of copra	0.1928	-0.2227	0.3938*	0.2088	0.5449**	0.7243**	0.8346**	0.1962	0.1289	0.4145**	0.4254**	0.6244**	0.7741**	----	
x15. Husk / nut ratio	-0.0522	0.5245**	-0.4180**	-0.1320	-0.3259*	-0.6988**	-0.6924**	-0.3712*	0.2068	-0.3047	-0.3087	-0.5868**	-0.6043**	-0.6656**	----

kernel and copra were found to be significantly and positively correlated with all characters and among themselves except oil content, polar diameter, thickness of husk, volume of nut water (correlated with weight of kernel) and thickness of meat and was negatively correlated with husk/nut ratio.

4.3 Embryo and kernel weight of open pollinated and selfed nuts

The analysis of variance for comparing the weight of embryo and kernel of open pollinated and selfed nuts are presented in Tables 16 and 17. The results indicated no significant difference in embryo weight of open pollinated and selfed nuts in KI and KII. However, the embryo weight differed significantly in KIII, WCT and NCD. The kernel weight of open pollinated and selfed nuts varied significantly in all the five varieties/types. The mean weight of embryo and kernel of open pollinated and selfed nuts are given in Table 18. They are represented by bar diagrams in Figures 13 and 14.

The embryo weight of open pollinated and selfed nuts were on par in KI and KII. However in KIII, the weight

Table 16. Weight of embryo of open pollinated and selfed nuts

ANOVA

Source		KI		KII		KIII		WCT		NCD	
	df	MSS	F	MSS	F	MSS	F	MSS	F	MSS	F
Open pollinated vs selfed	1	5.4×10^{-6}	0.13	0.00	0.00	4.6×10^{-4}	4.83*	4.0×10^{-3}	52.64**	5.9×10^{-3}	62.25**
Between nuts within open pollinated palms	9	3.2×10^{-4}	7.53**	6.4×10^{-4}	4.35**	4.5×10^{-4}	4.74**	1.0×10^{-3}	13.85**	3.2×10^{-4}	3.37**
Between nuts within selfed palms	9	3.0×10^{-4}	6.97**	7.0×10^{-4}	4.80**	4.9×10^{-4}	5.15**	5.3×10^{-4}	7.03**	1.2×10^{-3}	12.46**
Error	60	4.2×10^{-5}		1.5×10^{-4}		9.5×10^{-5}		7.5×10^{-5}		9.5×10^{-5}	

* - Significant at 5 per cent level.

** - Significant at 1 per cent level.

Table 17. Weight of kernel of open pollinated and selfed nuts

ANOVA

Source		KI		KII		KIII		WCT		NCD	
	df	MSS	F	MSS	F	MSS	F	MSS	F	MSS	F
Open pollinated vs selfed	1	6552.00	8.95**	40163.50	35.83**	32725.00	22.93**	2820.38	5.37*	44608.50	28.50**
Between nuts within open pollinated palms	9	6139.00	8.39**	3553.66	3.17**	26919.78	18.86**	9478.04	18.03**	11205.97	7.16**
Between nuts within selfed palms	9	5495.22	7.51**	9310.61	8.31**	17117.22	11.99**	7124.90	13.56**	26265.64	16.78**
Error	60	731.80		1120.93		1427.12		525.60		1565.48	

* - Significant at 5 per cent level.

** - Significant at 1 per cent level.

Table 18. Mean weight of embryo (g) and kernel (g) of open pollinated and selfed nuts

Variety/ type	Mean weight of embryo (g)		CD (0.05)	Mean weight of kernel (g)		CD (0.05)
	Open pollinated	Selfed		Open pollinated	Selfed	
KI	0.0844	0.0839	0.00271	305.88	323.98	11.157
KII	0.0848	0.0848	0.00546	283.58	328.39	15.170
KIII	0.0822	0.0870	0.00436	314.10	354.55	17.201
WCT	0.0542	0.0402	0.00385	161.30	149.43	10.255
NCD	0.0893	0.0721	0.00445	289.63	242.40	17.690

Fig.13. Weight of embryo of open pollinated vs selfed nuts

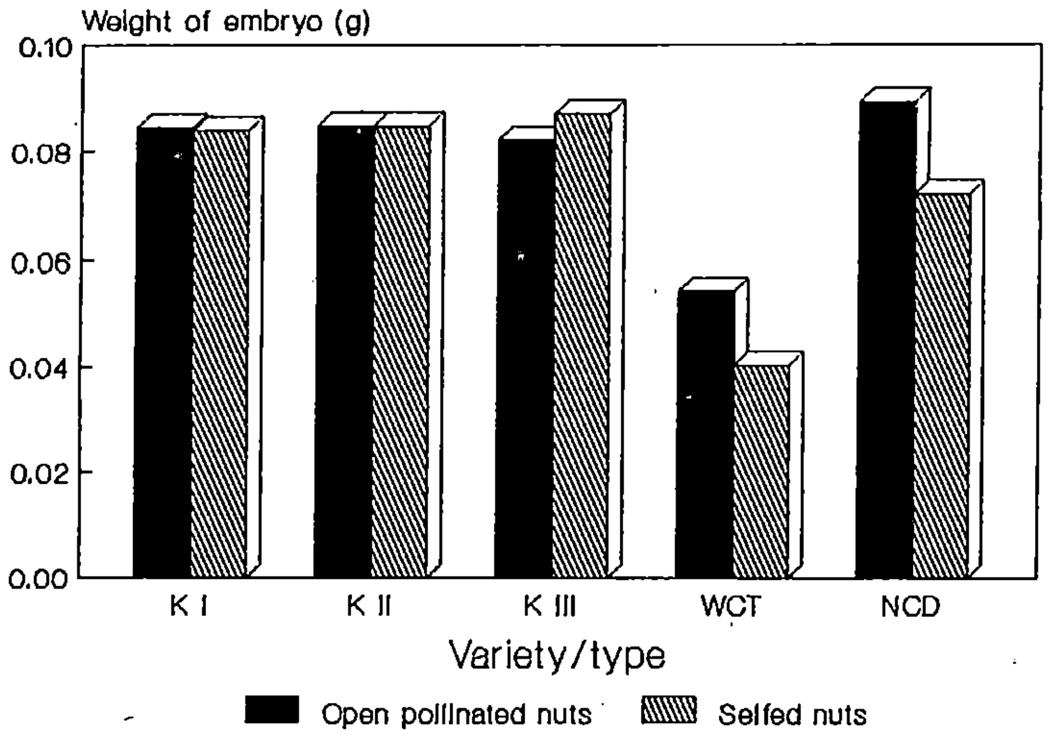
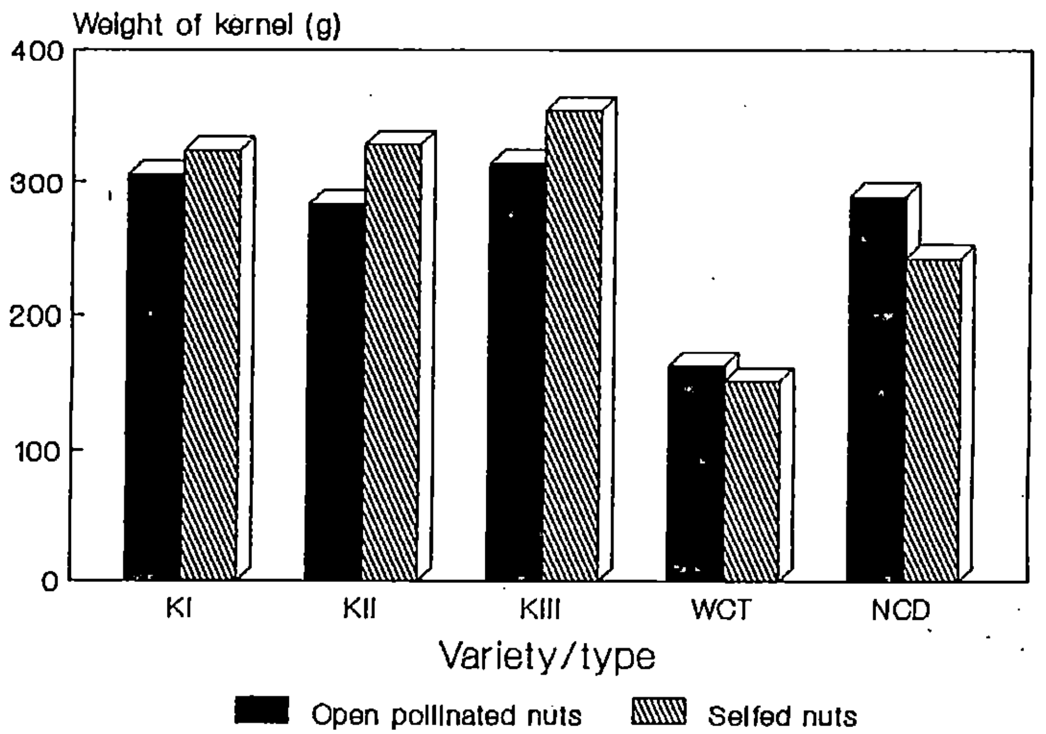


Fig.14. Weight of kernel of open pollinated vs selfed nuts



of embryo of selfed nuts was significantly superior to that of open pollinated nuts. In WCT and NCD the embryo weight of open pollinated nuts was significantly higher than those of selfed nuts. The mean kernel weight of open pollinated and selfed nuts showed that in KI, KII and KIII the kernel weight of selfed nuts was significantly superior to those of open pollinated nuts. However, in WCT and NCD the kernel weight of open pollinated nuts was significantly higher than that of selfed nut.

4.4 Seedling characters.

4.4.1 Germination

Table 19 shows the pooled analysis of variance of five varieties/types for germination percentage of nuts and days taken for germination. There was significant difference among the varieties/types for both these characters.

The germination percentage of nuts and days taken for germination are presented in Tables 20 and 21 respectively. KI recorded the maximum number of nuts germinated (90.76) and was significantly superior to all other varieties/types which were on par. The mean number of days taken for germination was lowest in K II (57.92 days)

Table 19. Germination of seednuts

ANOVA - Pooled

Source	df	Germination percentage of seednuts		Days taken for germination	
		MSS	F	MSS	F
Replication	3	0.59	0.31	1019.33	4.65
Varieties/types	4	7.96	4.14*	31373.31	143.11**
Error I	12	1.92		219.22	
Progenies	45	6.01	5.08**	871.11	3.18**
Error 2	135	1.18		273.81	

* - Significant at 5 per cent level.

** - Significant at 1 per cent level.

Table 20. Germination percentage of seednuts

Progenies	KI	KII	KIII	WCT	NCD	Mean
1.	94.93 (9.74)	92.31 (9.61)	37.11 (6.09)	87.31 (9.34)	89.56 (9.46)	80.24 (8.85)
2	92.31 (9.61)	32.73 (5.72)	97.45 (9.87)	54.50 (7.38)	23.88 (4.89)	60.17 (7.49)
3	84.63 (9.20)	87.31 (9.34)	34.82 (5.90)	51.96 (7.21)	94.93 (9.74)	70.73 (8.28)
4.	89.86 (9.48)	92.31 (9.61)	87.14 (9.34)	84.14 (9.17)	80.00 (8.94)	86.69 (9.31)
5.	97.45 (9.87)	89.86 (9.48)	77.09 (8.78)	59.30 (7.70)	86.64 (9.31)	82.07 (9.03)
6.	92.45 (9.62)	81.99 (9.06)	89.72 (9.47)	54.42 (7.38)	87.14 (9.34)	81.14 (8.97)
7.	76.40 (8.74)	36.28 (6.02)	89.56 (9.46)	81.10 (9.04)	79.49 (8.92)	72.71 (8.44)
8.	94.93 (9.74)	94.93 (9.74)	74.58 (8.64)	76.94 (8.77)	69.82 (8.36)	82.24 (9.05)
9.	92.31 (9.61)	84.79 (9.21)	81.99 (9.06)	79.56 (8.92)	52.10 (7.22)	78.15 (8.80)
10.	92.31 (9.61)	97.45 (9.87)	92.31 (9.61)	73.55 (8.58)	94.93 (9.74)	90.11 (9.48)
Mean	90.76 (9.52)	79.00 (8.77)	76.18 (8.62)	70.35 (8.35)	75.85 (8.59)	
$F_{9,27}$	0.67	8.94**	4.87**	2.23	7.12**	
SE	0.80	1.03	1.30	1.12	1.13	
CD(0.05) (i)	Varieties/types					= (0.636)
(ii)	2 progenies within same variety/type					= (1.509)
(iii)	,, ,, different ,, ,,					= (1.555)

Figures in parenthesis are values after square root transformation.

** - Significant at 1 per cent level.

Table 21. Number of days taken for germination

Progenies	KI	KII	KIII	WCT	NCD	Mean
1	112.70	51.55	117.77	122.61	128.82	106.69
2	128.54	31.83	82.88	140.45	128.17	102.37
3	124.02	68.98	135.11	136.14	124.54	117.76
4.	99.86	55.70	87.56	96.54	121.81	92.30
5.	117.01	61.77	127.44	132.06	114.83	110.62
6.	109.50	81.97	102.01	130.71	105.32	105.90
7.	131.81	46.19	94.76	113.15	132.67	103.72
8.	130.73	56.76	130.73	126.44	133.99	115.73
9.	110.16	75.03	74.64	134.73	124.76	103.86
10.	99.35	49.37	119.49	135.10	113.61	103.39
Mean	116.37	57.92	107.24	126.80	122.85	
$F_{9,27}$	8.06**	2.63*	3.87**	1.83	3.24**	
SE	8.51	18.12	22.04	19.49	10.14	

CD(0.05)
(i) Varieties/types = 6.794
(ii) 2 progenies within same variety/type = 23.168
(iii) ,, ,, different ,, ,, = 22.936

* - Significant at 5 per cent level.

** - Significant at 1 per cent level.

which was significantly lower when compared to all others. KIII (107.24 days) ranked second for early germination and it required significantly lesser number of days for germination than KI, WCT and NCD. The seednuts of WCT took maximum number of days for germination (126.80 days) which was on par with NCD (122.85 days).

4.4.2 Seedling characters at 5th month after germination.

Table 22 shows the pooled analysis of variance of seedling characters viz., height, number of leaves, girth at collar and total leaf area at 5th month after germination. The five varieties/types differed significantly among themselves for all these characters.

4.4.2.1 Height of seedling

Table 23 shows the height of seedling at 5th month after germination. The first generation Komadan showed the highest value (86.47cm) which was significantly superior to all others where as K II,KIII and NCD were on par. The lowest value for this character was shown by WCT (63.25 cm) which was significantly inferior to all other varieties/types. The progenies within varieties/types did not show any significant difference for this character

Table 22. Seedling characters at 5^{th} month after germination

ANOVA - Pooled

Source	df	Height		Number of leaves		Girth at collar		Total leaf area	
		MSS	F	MSS	F	MSS	F	MSS	F
Replications	3	268.50	1.16	0.50	1.21	4.18	4.63	1562229	5.73
Varieties/types	4	2894.90	12.54**	7.23	17.58**	13.10	14.49**	5803392	21.29**
Error I	12	230.85		0.41		0.90		272477.4	
Progenies	45	151.94	1.98**	0.27	1.66*	1.02	1.96**	229300.3	1.32
Error 2	135	76.86		0.16		0.52		173403.5	

* - Significant at 5 per cent level.

** - Significant at 1 per cent level.

Table 23.

Height of seedling (cm) at 5^{th} month after germination

Progenies	KI	KII	KIII	WCT	NCD	Mean
1.	84.93	82.90	83.92	66.28	77.19	79.04
2.	79.28	68.23	91.08	65.83	63.50	73.58
3.	86.23	80.52	85.46	56.42	70.35	75.80
4.	91.92	81.28	78.04	71.70	73.46	79.28
5.	86.53	84.29	70.16	64.59	80.21	77.16
6.	87.14	76.50	76.43	51.33	82.12	74.71
7.	80.20	75.46	73.64	65.26	72.97	73.51
8.	82.01	85.04	71.53	61.08	64.43	72.82
9.	93.56	82.82	76.12	64.55	74.86	78.38
10.	92.93	77.15	64.03	65.41	79.92	75.89
Mean	86.47	79.42	77.04	63.25	73.90	
$F_{9,27}$	2.00	2.04	4.11**	1.18	1.52	
SE	7.24	7.20	7.89	10.52	10.35	

CD(0.05) (i) Varieties/types = 6.972
(ii) 2 progenies within same variety/type = 12.275
(iii) '' different '' = 13.448

** - Significant at 1 per cent level.

except in KIII which showed significant difference in seedling height.

4.4.2.2 Number of leaves

Number of leaves at 5^{th} month after germination is given in Table 24. Maximum number of leaves was noticed in KII (4.89) which was on par with KI (4.69) and KIII(4.63). NCD (4.45) was found to be on par with KI and KIII for this character. WCT recorded the lowest value (3.78) and was significantly inferior to all others. The progenies within the varieties/types showed no significant difference except in KIII and NCD.

4.4.2.3 Girth at collar

Table 25 shows the girth at collar at 5^{th} month after germination. Girth at collar was maximum in KI (10.03 cm) and was on par with K III (9.78cm). K III and KII (9.58cm) were on par. Moreover, NCD was found to be on par with KII. The minimum value for this character was noticed in WCT seedlings (8.57cm) which was significantly inferior to all others. No significant difference was noticed among the progenies within the varieties/types except in K III and NCD.

Table 24. Number of leaves at 5th month after germination

Progenies	KI	KII	KIII	WCT	NCD	Mean
1.	4.71	5.48	4.96	3.77	4.25	4.63
2.	4.61	4.95	4.88	3.79	3.88	4.42
3.	4.43	4.77	5.02	3.65	4.48	4.47
4.	4.99	5.37	4.71	3.58	4.46	4.62
5.	4.64	4.63	4.34	3.83	4.82	4.45
6.	4.68	4.63	4.24	3.69	4.55	4.36
7.	4.58	4.78	4.70	3.77	4.24	4.41
8.	4.44	4.88	4.49	3.63	4.28	4.35
9.	5.01	4.75	4.84	3.84	4.67	4.62
10.	4.76	4.66	4.12	4.24	4.83	4.52
Mean	4.69	4.89	4.63	3.78	4.45	
$F_{9,27}$	1.37	1.41	2.67*	0.67	2.82*	
SE	0.33	0.51	0.39	0.45	0.35	

CD(0.05) (i) Varieties/types = 0.294
(ii) 2 progenies within same variety/type = 0.575
(iii) '' different '' = 0.615

* - Significant at 5 per cent level.

Table 25. Girth at collar (cm) at 5th month after germination

Progenies	KI	KII	KIII	WCT	NCD	Mean
1.	10.05	10.27	10.08	9.11	9.06	9.72
2.	9.89	9.04	10.22	8.64	7.92	9.14
3.	9.51	10.04	10.65	8.46	8.85	9.50
4.	10.21	9.92	10.05	8.81	9.27	9.65
5.	10.44	9.51	9.16	8.21	9.99	9.46
6.	9.86	9.25	9.54	7.82	9.51	9.20
7.	9.69	9.58	9.65	8.67	8.75	9.27
8.	9.60	9.67	9.27	8.09	5.71	9.07
9.	10.87	9.02	10.11	8.52	9.46	9.60
10.	10.20	9.50	9.02	9.41	10.13	9.65
Mean	10.03	9.58	9.78	8.57	9.17	
$F_{9,27}$	1.61	1.23	2.88*	1.26	3.27**	
SE	0.65	0.74	0.62	0.84	0.73	

CD(0.05) (i) Varieties/types = 0.436
(ii) 2 progenies within same variety/type = 1.010
(iii) '' different '' = 1.047

* - Significant at 5 per cent level.

** - Significant at 1 per cent level.

4.4.2.4 Total leaf area

Total leaf area (Table 26) was maximum in KI (1822.39 cm^2) which was significantly superior to all other varieties/types. KII and KIII which ranked second and third respectively in total leaf area were on par. WCT was having the lowest value for this character (900.46 cm^2) and next highest was NCD (943.36 cm^2) which were on par and significantly inferior to all the three groups of Komadan. The progenies showed no significant difference among themselves within the varieties/types.

4.4.2.5 Chlorophyll content at 5th month after germination

The pooled analysis of variance pertaining to chlorophyll `a', chlorophyll `b' and total chlorophyll are given in Table 27. Neither total chlorophyll nor its components showed any significant difference among the varieties/types. The mean values are given in Table 28.

4.4.3 Seedling characters at 9th month after germination

Table 29 shows the pooled analysis of variance of seedling characters viz height, number of leaves, girth at

Table 26. Total leaf area (cm^2) at 5^{th} month after germination

Progenies	KI	KII	KIII	WCT	NCD	Mean
1	1473.20	1629.84	1310.73	790.42	949.42	1230.72
2	1338.45	808.78	1781.02	653.18	1114.81	1139.25
3	1763.49	1602.16	992.33	628.10	898.96	1177.01
4	2065.40	1266.69	1276.51	989.54	924.07	1304.44
5	1540.83	1238.75	1121.13	1164.96	958.66	1204.87
6	1949.78	1615.08	1304.90	988.71	940.15	1359.72
7	1835.81	1430.85	1929.12	763.93	857.21	1363.38
8	1922.06	1351.59	1534.90	1068.88	838.55	1343.20
9	2173.39	1371.91	1503.99	940.58	873.48	1372.67
10	2161.48	1772.42	1192.25	1016.28	1078.25	1444.14
Mean	1822.39	1408.81	1394.69	900.46	943.36	
$F_{9,27}$	1.61	0.98	1.73	1.30	0.65	
SE	458.09	554.79	445.07	317.91	224.09	

CD(0.05) (i) Varieties/types = 239.512
(ii) 2 Progenies within same variety/type = 583.014
(iii) " different " = 599.438.

Table 27

Chlorophyll content in leaves at 5th month after germination

ANOVA - Pooled

Source	df	Chlorophyll 'a'		Chlorophyll 'b'		Total chlorophyll	
		MSS	F	MSS	F	MSS	F
Replication	3	0.74	2.30	0.02	0.91	0.95	2.00
Varieties/types	4	0.46	1.44	0.01	0.24	0.56	1.19
Error 1	12	0.32		0.02		0.47	
Progenies	20	0.04	0.88	0.01	0.83	0.07	0.81
Error 2	60	0.04		0.01		0.09	

Table 28

Chlorophyll content in leaves (mg/g) at 5th month after germination

Variety/type	Chlorophyll 'a' Mean	Chlorophyll 'b' Mean	Total chlorophyll Mean
KI	0.80	0.20	0.99
KII	0.49	0.17	0.66
KIII	0.83	0.20	1.03
UCT	0.88	0.22	1.09
NCD	0.81	0.20	1.01
CD(0.05)	--	--	--
SE	0.180	0.048	0.219

Table 29. Seedling characters and seedling vigour index at 9^{th} month after germination.

ANOVA - Pooled

Source	df	Height of seedling		Number of leaves		Girth at collar		Total leaf area		Seedling vigour index		Percentage of quality seedlings	
		MSS	F	MSS	F	MSS	F	MSS	F	MSS	F	MSS	F
Replication	3	74.58	0.13	2.25	5.45	4.02	1.52	2768384	1.66	0.78	4.65	533.83	
Varieties/ types	4	4808.90	8.09**	13.01	31.40**	27.56	10.42**	35818630	21.53**	5.59	33.13**	2831.25	3.30*
Error 1	12	594.78		0.41		2.64		1663872		0.16		859.25	
Progenies	45	382.21	2.77**	0.66	1.84**	2.28	2.24**	3132813	2.04**	0.27	2.01**	1477.5	4.87**
Error 2	135	137.74		0.35		1.02		1536530		0.13		303.42	

* - Significant at 5 percent level.

** - Significant at 1 percent level.

collar, total leaf area and seedling vigour index pertaining to the five varieties/types at 9^{th} month after germination.

Similar to the results of 6^{th} month there were significant differences among the five varieties/types regarding the above mentioned characters at 9^{th} month also (Fig.15- a to e).

4.4.3.1 Height of seedling

The mean height of seedling presented in Table 30 shows that height was maximum for the seedlings in KI (115.39cm) which was on par with KII (108.75 cm) and significantly superior to others. K II was on par with NCD (100.10cm) where as NCD and K III (96.84 cm) were found to be on par and NCD was significantly superior to WCT which recorded the lowest value (86.95cm). However KIII and WCT were on par. The progenies within the varieties/types showed significant difference for this character except for KII.

4.4.3.2 Number of leaves

Table 31 shows the mean number of leaves in seedlings at 9^{th} month after germination. Number of leaves was maximum in KII (7.61) which was on par with KI (7.33) and significantly superior to others. KIII (7.26) was on par with KI and was significantly superior to NCD and WCT.

Fig. 15 - a. Seedlings of KI at 9^{th} month after germination

Fig. 15 - b. Seedlings of KII at 9^{th} month after germination

Fig. 15 - c. Seedlings of KIII at 9^{th} month after germination

Figure 15- a

Figure 15-b

Figure 15-c

Fig. 15 - d. Seedlings of WCT at 9th month after germination

Fig. 15 - e. Seedlings of NCD at 9th month after germination

Figure 15-d

Figure 15-e

Table 30.

Height of seedling (cm)at 9^{th} month after germination

Progenies	KI	KII	KIII	WCT	NCD	Mean
1.	111.93	110.28	97.08	80.98	109.40	101.93
2.	108.60	95.33	120.18	88.02	85.03	99.43
3.	111.04	114.60	100.24	68.40	96.78	98.21
4.	127.34	103.44	104.27	103.56	102.25	108.17
5.	112.90	113.61	88.73	83.82	106.16	101.04
6.	115.92	99.15	99.09	72.21	111.96	99.67
7.	102.01	110.77	93.09	94.27	98.03	99.63
8.	109.35	116.57	85.12	87.11	84.98	96.63
9.	137.56	113.02	99.01	95.44	102.86	109.58
10.	117.21	110.69	81.58	95.64	103.58	101.74
Mean	115.39	108.75	96.84	86.95	100.10	
$F_{9,27}$	2.71*	1.04	5.09**	4.16**	2.52*	
SE	12.39	13.86	9.67	10.77	11.57	

CD(0.05) (i) Varieties/types = 11.190
(ii) 2 progenies within same variety/type = 16.432
(iii) ,, ,, different ,, ,, = 18.963

* - Significant at 5 per cent level.

** - Significant at 1 per cent level.

Table 31. Number of leaves at 9th month after germination

Progenies	KI	KII	KIII	WCT	NCD	Mean
1.	7.20	7.91	7.40	5.92	6.66	7.02
2.	7.25	7.58	7.84	6.12	5.95	6.95
3.	6.73	7.55	7.13	5.54	6.50	6.69
4.	7.63	7.92	7.48	6.63	7.04	7.34
5.	7.10	7.47	6.86	6.11	7.10	6.93
6.	7.61	7.24	7.00	5.44	7.73	7.00
7.	7.29	7.67	7.46	6.71	6.93	7.21
8.	7.06	7.74	6.77	5.91	6.95	6.89
9.	7.87	7.26	7.69	6.44	7.65	7.38
10.	7.58	7.70	6.98	6.34	7.78	7.28
Mean	7.33	7.61	7.26	6.12	7.03	
$F_{9,27}$	1.51	0.51	1.89	1.24	7.37**	
SE	0.55	0.66	0.53	0.77	0.43	

CD(0.05) (i) Varieties/types = 0.295
(ii) 2 progenies within same variety/type = 0.840
(iii) ,, ,, different ,, ,, = 0.846

** - Significant at 1 per cent level.

The lowest value was shown by WCT (6.12) which was significantly inferior to all others. There was no significant difference among the progenies within the varieties/types except for NCD.

4.4.3.3 Girth at collar

Table 32 shows the girth at collar at 9^{th} month after germination. The seedlings in KII recorded maximum girth at collar (11.97cm) which was on par with KI (11.52 cm) and significantly superior to all other varieties/types. K III and NCD were on par with KI for this character. The girth was minimum for the seedlings in WCT (9.78 cm) which was significantly inferior to all other varieties/types. The progenies differed significantly among themselves within the varieties/types except in KII and KIII.

4.4.3.4 Total leaf area

Total leaf area presented in Table 33 was maximum for the seedlings in K II (4836.80 cm ^{2}) which was significantly superior to all others. KI and KIII were on par for this character but significantly superior to both WCT and NCD. WCT (2569.23 cm ^{2}) which recorded the lowest

Table 32. Grith at collar (cm) at 9th month after germination

Progenies	KI	KII	KIII	WCT	NCD	Mean
1.	11.35	12.87	12.10	9.81	10.54	11.34
2.	11.06	11.77	12.67	9.63	9.85	11.00
3.	11.01	12.44	11.17	8.85	10.03	10.70
4.	12.57	12.03	11.58	10.20	10.85	11.45
5.	12.19	11.34	9.95	9.07	12.00	10.91
6.	11.23	11.06	11.26	9.82	11.70	11.02
7.	10.68	12.69	10.99	10.38	10.11	10.97
8.	10.71	12.19	9.75	9.34	9.70	10.34
9.	12.25	11.02	11.71	10.27	11.34	11.32
10.	12.14	12.24	10.26	10.38	11.80	11.37
Mean	11.52	11.97	11.14	9.78	10.79	
$F_{9,27}$	3.91**	0.8728	2.05	3.05*	5.62**	
SE	0.71	1.40	1.31	0.63	0.73	

CD(0.05) (i) Varieties/types = 0.746
(ii) 2 progenies within same variety/type = 1.415
(iii) ,, ,, different ,, ,, = 1.523

* - Significant at 5 per cent level.

** - Significant at 1 per cent level.

Table 33. Total leaf area (cm^2) at 9^{th} month after germination

Progenies	KI	KII	KIII	WCT	NCD	Mean
1.	4110.04	5341.04	3918.44	2001.59	3109.26	3969.07
2.	4800.52	2795.46	7757.59	2071.79	2348.45	3954.76
3.	3987.93	5925.62	3492.02	1886.85	2522.89	3563.06
4.	4233.07	5025.52	3324.00	3227.37	2795.15	3721.02
5.	2996.08	3852.75	2707.55	1771.90	2543.43	2774.34
6.	4468.89	5196.49	4487.59	2327.79	3131.39	3922.43
7.	3729.23	4786.71	5262.52	2930.46	2578.69	3857.52
8.	3697.47	5292.72	3130.74	2828.76	2798.07	3549.55
9.	4185.55	5845.97	3744.16	3631.47	3444.35	4170.34
10.	4737.39	4305.70	3875.74	3014.35	3757.33	3938.10
Mean	4094.62	4836.80	4170.04	2569.23	2902.90	
$F_{9,27}$	1.476	1.066	3.85**	2.14	1.57	
SE	882.72	1854.61	1477.03	874.63	719.21	

CD(0.05) (i) Varieties/types = 591.865
(ii) 2 progenies within same variety/type = 1735.484
(iii) ,, ,, different ,, ,, = 1742.661

** - Significant at 1 per cent level.

value for this character was on par with NCD (2902.90 cm^2). There was no significant difference among the progenies within the varieties/types except for KIII.

4.4.3.5 Seedling vigour index

Table 34 shows the seedling vigour index computed based on the seedling characters at 9th month after germination and days taken for germination. The second generation Komadan recorded the highest seedling vigour index of 4.68 which was significantly superior to all other varieties / types. KI which had a vigour index of 4.47 was on par with KIII (4.40). NCD (4.25) was found to be on par with KIII and was significantly superior to WCT which recorded the lowest vigour index value (3.69). Significant difference among the progenies for vigour index was noticed only in K III and NCD.

4.4.3.6 Chlorophyll content in leaves at 9th month after germination

Table 35 shows the pooled analysis of variance of total chlorophyll and its components chlorophyll `a' and `b' in the leaves of seedlings at 9th month after germination. There was significant difference between the varieties/types

Table 34. Seedling vigour index

Progenies	KI	KII	KIII	WCT	NCD	Mean
1.	4.39	4.88	4.48	3.57	4.05	4.27
2.	4.39	4.66	4.82	3.67	3.59	4.23
3.	4.10	4.65	4.30	3.30	3.93	4.06
4.	4.69	4.85	4.56	4.05	4.26	4.48
5.	4.34	4.59	4.12	3.66	4.33	4.21
6.	4.63	4.41	4.26	3.27	4.70	4.25
7.	4.39	4.74	4.52	4.06	4.17	4.38
8.	4.28	4.77	4.05	3.56	4.15	4.16
9.	4.83	4.45	4.69	3.89	4.62	4.50
10.	4.64	4.75	4.19	3.83	4.71	4.42
Mean	4.47	4.68	4.40	3.69	4.25	
$F_{9,27}$	1.76	0.55	2.28*	1.41	7.66**	
SE	0.34	0.42	0.34	0.46	0.26	

CD(0.05) (i) Varieties/types = 0.189
(ii) 2 progenies within same variety/type = 0.518
(iii) ,, ,, different ,, ,, = 0.524

* - Significant at 5 per cent level.

** - Significant at 1 per cent level.

TABLE 35.

Chlorophyll content in leaves at 9th month after germination

ANOVA - Pooled

Source	df	Chlorophyll 'a'		Chlorophyll 'b'		Total chlorophyll	
		MSS	F	MSS	F	MSS	F
Replication	3	0.0583	2.18	0.0161	0.81	0.0158	0.21
Varieties/types	4	0.2883	10.79**	0.0499	2.51	0.5552	7.34**
Error 1	12	0.0267		0.0198		0.0757	
Progenies	20	0.1083	2.82	0.0105	1.71	0.1751	2.88
Error 2	60	0.0384		0.0061		0.0608	

** - Significant at 1 percent level

Table 36. Chlorophyll content in leaves (mg/g) at 9th month after germination

Variety/type	Chlorophyll 'a' Mean	Chlorophyll 'b' Mean	Total chlorophyll Mean
KI	1.20	0.31	1.50
KII	1.08	0.27	1.34
KIII	0.96	0.25	1.20
WCT	0.93	0.20	1.13
NCD	0.92	0.19	1.10
CD(0.05)	0.112	----	0.190
S E	0.052	0.045	0.087

for chlorophyll `a' and total chlorophyll where as no significant difference was noticed for chlorophyll `b'.

The mean values of chlorophyll `a', `b' and total chlorophyll are given in Table 36. KI had the maximum chlorophyll `a' content (1.20mg/g) and was significantly superior to all others. K II (1.08 mg/g) was significantly superior to K III, WCT and NCD which were all on par for this character. There was no significant difference among varieties/types for chlorophyll `b'. Total chlorophyll content was maximum in KI (1.50 mg/g) which was on par with KII (1.34 mg/g) and significantly superior to KIII, WCT and NCD. The latter three were on par for this character.

4.4.4 Growth increment in seedling characters between 5^{th} and 9^{th} months after germination

The pooled analysis of variance relating to growth increment in four seedling characters between 5^{th} and 9^{th} months pertaining to the five varieties/types are given in Table 37. Significant difference among the five varieties/types was noticed for all characters except height of seedling.

Table 37.

Growth increment in seedling characters between 5^{th} and 9^{th} months after germination

ANOVA - Pooled

Sl. No.	Character	Replication df=3		Varieties/ types df=4		Error 1 df=12	Progenies df=45		Error 2 df=135
		MSS	F	MSS	F	MSS	MSS	F	MSS
1.	Height of seedling	155.54	0.37	625.43	1.49	418.55	122.84	2.41**	50.99
2.	Number of leaves	1.64	7.90	0.84	4.05*	0.20	0.38	1.71**	0.22
3.	Girth at collar	6.49	3.85	8.37	4.96*	1.69	0.94	1.66*	0.56
4.	Total leaf area	6646699	3.70	19404960	10.80**	1796683	2529499	1.87**	1352113

* - Significant at 5 per cent level.

** - Significant at 1 per cent level.

Mean data on growth increment in seedling characters viz. height of seedling, number of leaves, girth at collar and total leaf area are presented in Tables 38 to 41.

4.4.4.1 Increment in height of seedling.

There was no significant difference among the varieties /types for increment in height of seedlings. The progenies in K III, WCT and NCD showed significant difference among themselves.

4.4.4.2 Increment in number of leaves

The three Komadan types and NCD were on par and significantly superior to WCT which recorded the lowest value (2.34). There was no significant difference among the progenies in the varieties/types except in NCD.

4.4.4.3 Increment in girth at collar

KII recorded the maximum increment in girth at collar (2.38 cm) between 5^{th} and 9^{th} months and was significantly superior to the other four varieties/types which were on par. The progenies within the varieties/types

Table 38. Growth increment in height of seedling (cm)

Progenies	KI	KII	KIII	WCT	NCD	Mean
1.	27.01	27.39	13.16	14.69	32.21	22.89
2.	29.32	27.11	29.10	22.19	21.53	25.85
3.	24.81	34.08	14.78	11.99	26.43	22.42
4.	35.42	22.16	26.23	31.85	28.79	28.89
5.	26.38	29.32	18.57	19.23	25.94	23.89
6.	28.78	22.65	22.66	20.88	29.84	24.96
7.	21.81	35.31	19.45	29.01	25.05	26.13
8.	27.35	31.54	13.58	26.03	20.55	23.81
9.	44.00	30.20	22.89	30.89	28.00	31.20
10.	24.28	33.54	17.56	30.23	23.66	25.85
Mean	28.92	29.33	19.80	23.70	26.20	
$F_{9,27}$	2.20	0.97	2.84*	8.11**	1.79	
SE	8.65	9.23	6.38	4.93	5.47	

CD(0.05) (i) Varieties/types = 9.387
(ii) 2 progenies within same variety/type = 9.998
(iii) ,, ,, different ,, ,, = 13.115

* - Significant at 5 per cent level.

** - Significant at 1 per cent level.

Table 39. Growth increment in number of leaves

Progenies	KI	KII	KIII	WCT	NCD	Mean
1.	2.49	2.43	2.44	2.15	2.41	2.39
2.	2.64	2.63	2.97	2.33	2.08	2.53
3.	2.30	2.79	2.10	1.89	2.02	2.22
4.	2.64	2.55	2.77	3.05	2.58	2.72
5.	2.45	2.84	2.52	2.29	2.28	2.48
6.	2.93	2.61	2.75	1.75	3.17	2.64
7.	2.71	2.89	2.76	2.94	2.69	2.80
8.	2.62	2.87	2.28	2.27	2.66	2.54
9.	2.86	2.51	2.86	2.60	2.98	2.76
10.	2.83	3.04	2.86	2.10	2.95	2.76
Mean	2.65	2.72	2.63	2.34	2.58	
$F_{9,27}$	0.85	0.89	1.51	1.85	3.25**	
SE	0.42	0.42	0.46	0.62	0.43	

CD(0.05) (i) Varieties/types = 0.209
(ii) 2 progenies within same variety/type = 0.666
(iii) ,, ,, different ,, ,, = 0.664

** - Significant at 1 per cent level.

Table 40. Growth increment in girth at collar (cm)

Progenies	KI	KII	KIII	WCT	NCD	Mean
1.	1.30	2.59	2.02	0.71	1.48	1.62
2.	1.17	2.73	2.45	1.00	1.93	1.86
3.	1.50	2.40	0.52	0.39	1.18	1.20
4.	2.36	2.12	1.52	1.39	1.58	1.79
5.	1.75	1.83	0.79	0.86	2.00	1.45
6.	1.38	1.81	1.72	2.00	2.19	1.82
7.	0.98	3.10	1.34	1.70	1.36	1.70
8.	1.11	2.52	0.48	1.26	1.00	1.27
9.	1.38	2.00	1.60	1.75	1.89	1.73
10.	1.94	2.74	1.25	0.97	1.66	1.71
Mean	1.49	2.38	1.37	1.20	1.63	
$F_{9,27}$	3.20**	0.86	1.51	2.87*	1.89	
SE	0.47	0.93	1.04	0.60	0.56	
CD(0.05)	(i) Varieties/types				=	0.596
	(ii) 2 progenies within same variety/type				=	1.054
	(iii) ,, ,, different ,, ,,				=	1.154

* - Significant at 5 per cent level.

** - Significant at 1 per cent level.

Table 41. Growth increment in total leaf area (cm^2)

Progenies	KI	KII	KIII	WCT	NCD	Mean
1.	2636.84	3711.20	2607.71	1211.17	2159.84	2465.35
2.	3462.07	1986.68	5976.58	1418.61	1233.64	2815.52
3.	2224.45	4323.47	2499.69	1258.75	1623.93	2386.06
4.	2167.66	3758.83	2047.49	2237.83	1871.08	2416.58
5.	1455.26	2613.99	1586.42	606.94	1574.76	1569.48
6.	2519.11	3581.41	3182.69	1339.08	2191.34	2562.71
7.	1893.43	3355.87	3333.40	2166.53	1721.48	2494.14
8.	1775.41	3941.13	1595.84	1759.88	1959.52	2206.35
9.	2012.16	4474.06	2240.16	2690.89	2571.06	2797.67
10.	2575.91	2533.27	2683.49	1998.07	2679.08	2493.94
Mean	2272.23	3427.99	2775.35	1668.78	1959.56	
$F_{9,27}$	1.79	0.83	3.95**	1.93	1.65	
SE	838.98	1775.97	1274.87	885.41	702.41	

CD(0.05) (i) Varieties/types = 615.033
(ii) 2 progenies within same variety/type = 1628.009
(iii) ,, ,, different ,, ,, = 1654.559

** - Significant at 1 per cent level.

showed no significant difference among themselves except those in K I and WCT.

4.4.4.4 Increment in total leaf area

Increment in total leaf area was maximum in KII (3427.99 cm ^{2}) which was significantly superior to all others. K III and K I were on par and followed K II. However, K I was on par with NCD and WCT. There was no significant difference among the progenies with in the varieties/types except in K III where the progenies differed significantly.

4.4.5. Seedling characters at 12th month after sowing

The pooled analysis of variance relating to the seedling characters height, number of leaves, girth at collar and number of seedlings with split leaves at 12th month after sowing are given in Table 42. There was significant difference among the varieties/types in respect of the above characters.

Table 42. Seedling characters at 12^{th} month after sowing

ANOVA - Pooled

Source	df	Height		Number of leaves		Girth at collar		Total leaf area	
		MSS	F	MSS	F	MSS	F	MSS	F
Replication	3	141.83	0.13	7.80	6.53	9.90	1.61	2.89	0.61
Varieties/types	4	9919.00	9.03**	17.30	14.49**	50.52	8.19**	25.97	5.46**
Error I	12	1098.95		1.19		6.16		4.75	
Progenies	45	500.16	1.63*	1.07	2.08**	4.26	1.83**	5.12	2.81**
Error 2	135	307.32		0.51		2.32		1.82	

* - Significant at 5 per cent level.

** - Significant at 1 per cent level.

4.4.5.1 Height of seedling

The mean height of seedling at 12th month after sowing are given in Table 43. The second generation Komadan recorded the maximum height for seedlings (126.68 cm) and was on par with K I (121.87 cm). These were significantly superior to all other varieties/types. K III (104.71 cm) was found to be on par with NCD (101.50 cm). The minimum height was noticed for WCT seedlings (88.03 cm) which was on par with NCD seedlings. No significant difference among the progenies was noticed within the varieties/types except in K III and WCT.

4.4.5.2 Number of leaves

Table 44 shows the mean number of leaves at 12th month after sowing. Number of leaves was maximum in K II (8.22) which was on par with K III (7.74) and significantly superior to the other varieties/types. However, K I (7.52) and NCD (7.33) were found to be on par with K III and were significantly superior to WCT which recorded the lowest value for this character (6.43). There was no significant difference among the progenies within the varieties/types except in K III and NCD.

Table 43. Height of seedling (cm) at 12th month after sowing

Progenies	KI	KII	KIII	WCT	NCD	Mean
1.	118.14	121.63	101.30	86.26	110.64	107.59
2.	117.90	123.50	134.97	82.63	81.63	108.13
3.	117.82	130.66	106.26	71.65	95.57	104.39
4.	134.89	121.04	112.15	115.08	103.64	117.36
5.	119.58	130.75	91.86	87.67	105.98	107.17
6.	122.77	111.60	108.19	75.75	117.26	107.11
7.	104.01	130.22	101.81	92.06	102.85	106.19
8.	116.91	142.61	89.41	88.02	85.34	104.46
9.	142.27	127.54	112.62	91.98	104.17	115.71
10.	124.43	127.29	88.48	89.19	107.88	107.47
Mean	121.87	126.68	104.71	88.03	101.50	
$F_{9,27}$	2.25	0.37	4.73**	2.27*	2.21	
SE	13.98	26.82	12.75	15.45	14.86	

CD(0.05)
(i) Varieties/types = 15.211
(ii) 2 progenies within same variety/type = 24.544
(iii) ,, ,, different ,, ,, = 27.525

* - Significant at 5 per cent level.

** - Significant at 1 per cent level.

Table 44. Number of leaves at 12[th] month after sowing

Progenies	KI	KII	KIII	WCT	NCD	Mean
1.	7.44	8.29	8.18	6.06	6.89	7.37
2.	7.50	8.38	8.44	6.31	5.97	7.32
3.	6.89	7.95	7.50	5.72	6.64	6.94
4.	7.98	8.75	8.40	7.16	7.38	7.93
5.	7.18	7.78	6.95	6.46	7.48	7.17
6.	7.74	7.79	7.44	6.27	8.07	7.46
7.	7.31	8.40	7.81	6.98	7.28	7.56
8.	7.13	8.61	7.01	6.00	7.29	7.21
9.	8.13	7.67	8.31	6.74	8.00	7.77
10.	7.87	8.62	7.32	6.64	8.29	7.75
Mean	7.52	8.22	7.74	6.43	7.33	
$F_{7,27}$	1.64	0.74	2.53*	1.55	6.73**	
SE	0.63	0.92	0.72	0.73	0.54	

CD(0.05) (i) Varieties/types = 0.501
(ii) 2 progenieswithin same variety/type = 1.006
(iii) ,, ,, different ,, ,, = 1.070

* - Significant at 5 per cent level.

** - Significant at 1 per cent level.

4.4.5.3 Girth at collar

Girth at collar at 12th month after sowing presented in Table 45 shows that the second generation Komadan which recorded the maximum value (13.60cm) was on par with KI (12.53cm) and significantly superior to all other varieties/types. K III and NCD which showed mean girths of 12.21 cm and 11.60 cm respectively were on par with KI and were significantly superior to WCT which recorded the minimum girth at collar for the seedlings (10.35cm). Significant difference among the progenies was noticed only in K I and NCD.

4.4.5.4 Number of seedlings with split leaves

Table 46 shows the mean number of seedlings with split leaves at 12th month after sowing. Number of seedlings with split leaves was highest in K II (2.20) which was on par with K I (1.68) and significantly superior to all others. K III and NCD which had a mean number of seedlings with split leaves of 1.15 and 0.80 respectively were found to be on par with K I. The lowest value for this character was noticed in WCT (0.10) which was significantly inferior to all the Komadan types and NCD.

Table 45. Girth at collar (cm) at 12th month after sowing

Progenies	KI	KII	KIII	WCT	NCD	Mean
1.	12.54	14.64	13.15	10.93	11.05	12.46
2.	12.06	13.75	14.34	9.77	9.84	11.99
3.	12.16	13.88	12.58	9.41	10.74	11.75
4.	13.65	13.31	12.69	11.38	11.55	12.51
5.	13.27	12.17	10.40	9.74	12.86	11.69
6.	12.30	11.72	12.32	10.18	12.66	11.83
7.	11.01	14.39	12.00	11.09	11.14	11.93
8.	11.50	13.66	10.27	9.61	10.60	11.13
9.	13.46	11.84	13.24	10.68	12.27	12.30
10.	13.14	14.25	11.15	10.72	13.28	12.51
Mean	12.53	13.60	12.21	10.35	11.60	
$F_{9,27}$	3.46**	1.25	1.40	1.59	4.80**	
SE	0.93	1.93	2.19	1.11	1.02	

CD(0.05)
(i) Varieties/types = 1.140
(ii) 2 progenies within same variety/type = 2.135
(iii) ,, ,, different ,, ,, = 2.304

** - Significant at 1 per cent level.

Table 46. Number of seedlings with split leaves

Progenies	KI	KII	KIII	WCT	NCD	Mean
1.	1.50	3.50	1.25	0.50	1.75	1.70
2.	0.00	0.75	4.75	0.00	0.00	1.10
3.	0.00	3.00	0.25	0.00	1.50	0.95
4.	2.75	3.50	2.25	0.25	0.50	1.85
5.	2.50	1.25	0.00	0.00	0.75	0.90
6.	3.50	0.75	0.75	0.00	0.25	1.05
7.	0.00	1.50	0.50	0.00	0.75	0.55
8.	0.75	1.75	0.00	0.00	0.00	0.50
9.	3.00	1.25	1.50	0.00	1.50	1.45
10.	2.75	4.75	0.25	0.25	1.00	1.80
Mean	1.68	2.20	1.15	0.10	0.80	
$F_{9,27}$	2.58**	2.40*	5.32**	1.32	1.29	
SE	1.73	1.79	1.26	0.30	1.11	

CD(0.05) (i) Varieties/types = 1.000
(ii) 2 progenies within same variety/type = 1.890
(iii) ,, ,, different ,, ,, = 2.036

* - Significant at 5 per cent level.

** - Significant at 1 per cent level.

The three seedling character viz.,height, number of leaves and girth at collar pertaining to five varietties/types at 5^{th} and 9^{th} months after germination and at 12^{th} month after sowing are represented by bar diagrams in Figures 16 to 18.

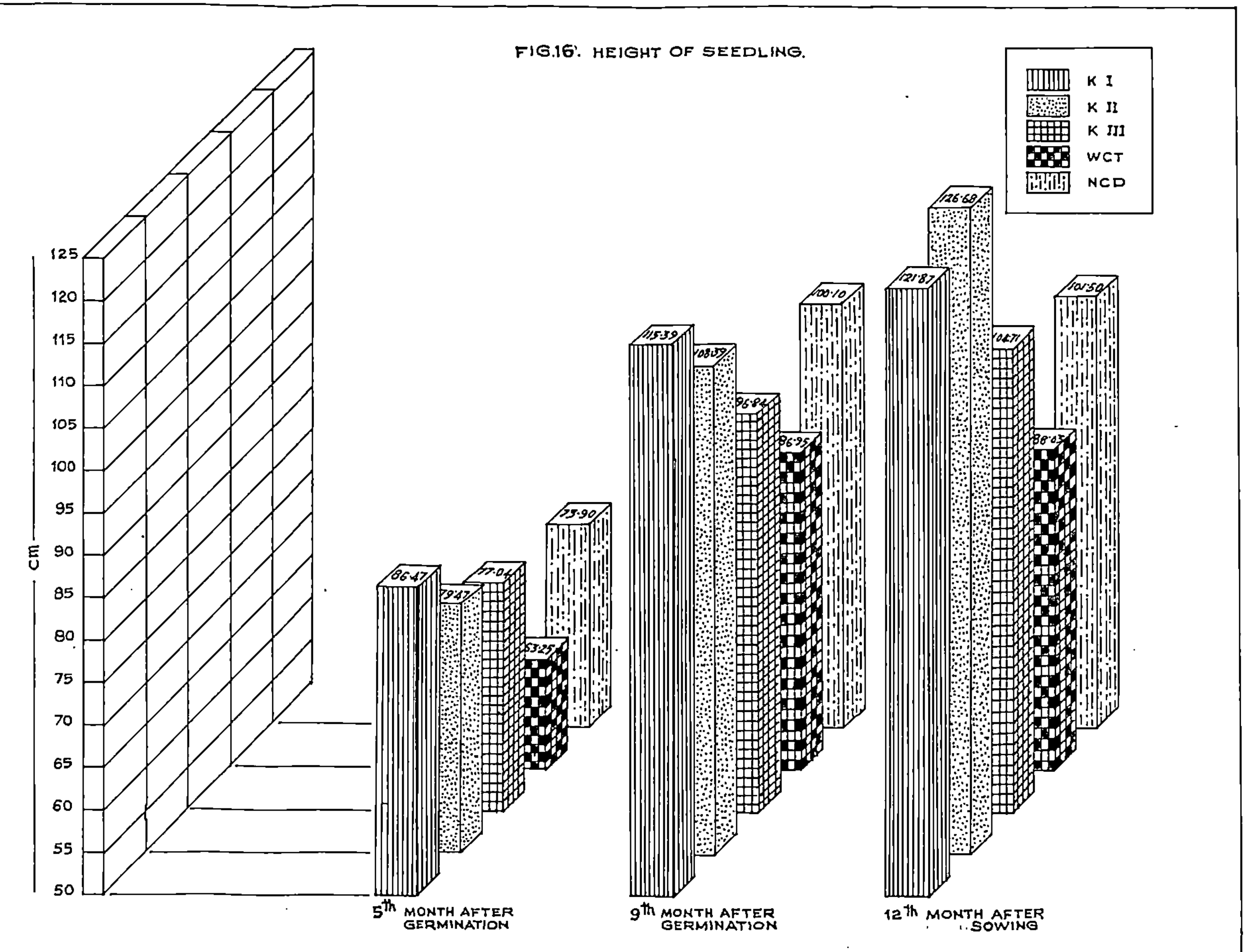
4.4.6 Colour of seedlings

Variations in the colour of petiole of the seedlings are shown in Figure 19. The percentage analysis of the petiole colour of seedlings is given in Table 47.

In KI 83.78 per cent of seedlings had petiole colours ranging from 2.5YR 3/3 (moderate reddish brown) to 7.5YR 5/7 (strong yellowish brown), while 15.66 per cent had olive shade. The per cent of seedlings with dark orange yellow petiole was only 0.57 in this type.

In KII 95.63 per cent of seedlings had petiole colours ranging from 2.5 YR 3/3 to 7.5 YR 5/7. The percentage of seedlings with olive shade petioles was only 3.7 and those with dark orange yellow was 0.67 per cent.

FIG.16'. HEIGHT OF SEEDLING.



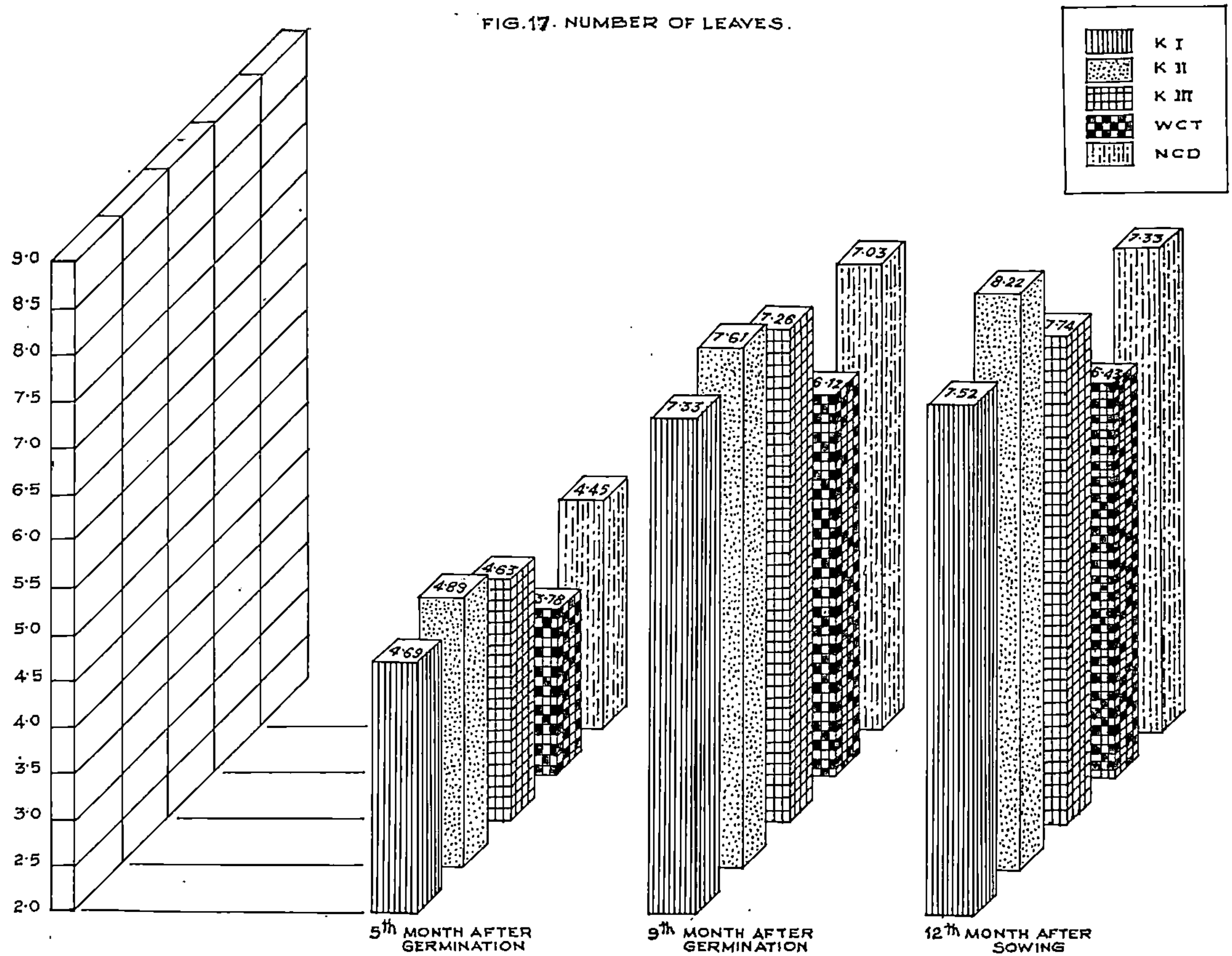


FIG. 17. NUMBER OF LEAVES.

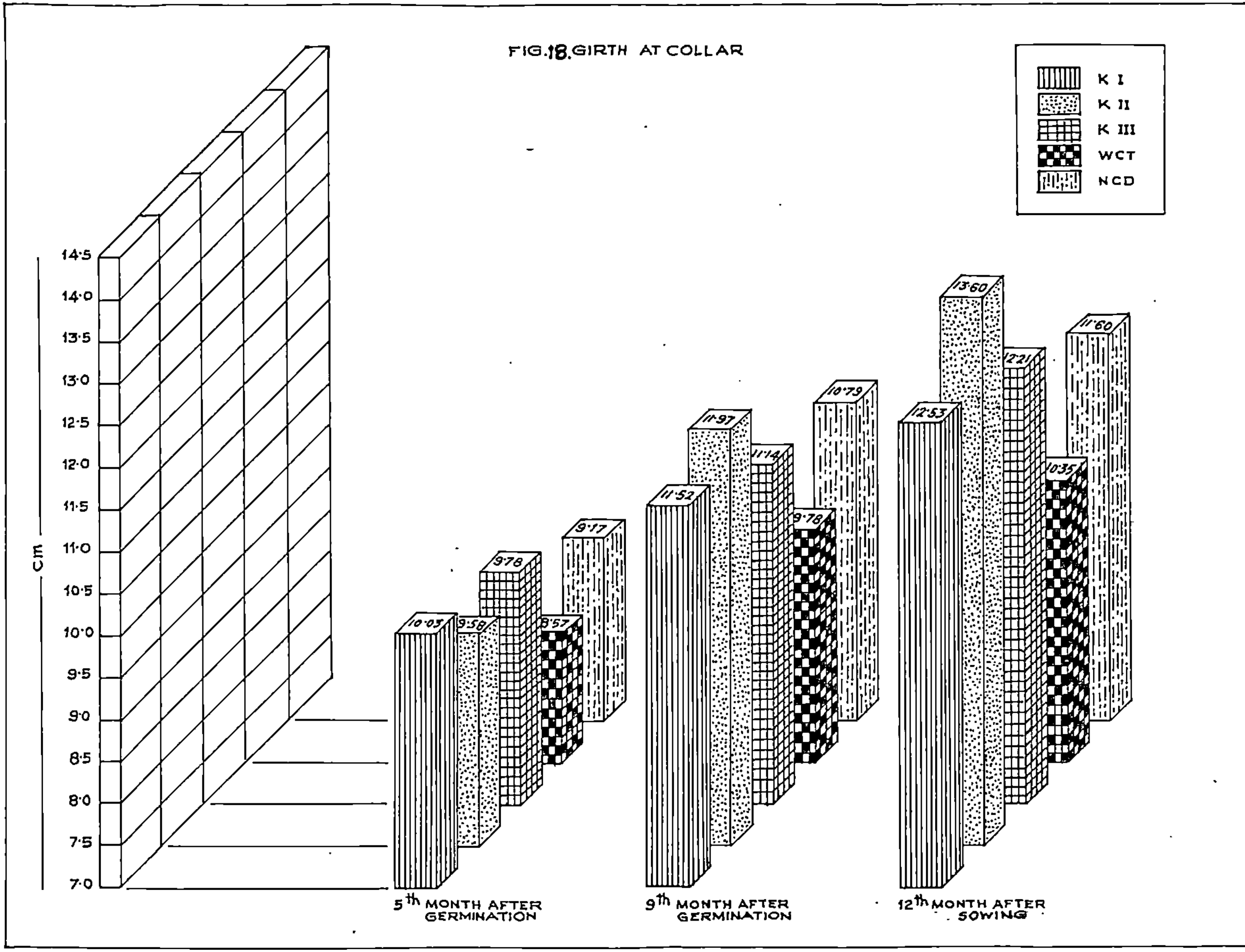


FIG.18.GIRTH AT COLLAR
K I
K II
K III
WCT
NCD
cm
14·5
14·0
13·5
13·0
12·5
12·0
11·5
11·0
10·5
10·0
9·5
9·0
8·5
8·0
7·5
7·0
10·03
9·58
9·78
8·57
9·17
11·52
11·97
11·14
9·78
10·79
12·53
13·60
12·21
10·35
11·60
5th MONTH AFTER GERMINATION
9th MONTH AFTER GERMINATION
12th MONTH AFTER SOWING

In K III 94.89 per cent of seedlings conformed to colour range from 2.5 YR 3/3 to 7.5 YR 5/7 while 5.1 per cent of seedlings had light and moderate olive shades.

Only 0.36 per cent of seedlings had petiole colour ranging from 2.5 YR 3/3 to 7.5 YR 5/7 in WCT. The major portion of the seedlings (97.47 per cent) in WCT had petiole colour with green and olive shades of 10 GY 3/2, 5 GY 4/3, 2.5 Y 3/1, 5 Y 5/6 and 7.5 Y 4/3.

In NCD 77.88 per cent of seedlings had brownish shades (2.5 YR 3/3 to 7.5 YR 5/7). Percentage of seedlings with olive shades was 10.89 while those with dark orange yellow petiole was 7.59 per cent.

4.4.7 Recovery of quality seedlings

Table 48 shows the percentage of quality seedlings to total number of seednuts.

Percentage recovery of quality seedlings was highest in K I (62) which was on par with K II (55.25 per cent) and K III (54.95 per cent) and significantly superior to others. NCD (52.50 per cent) was found to be on par with K II and K III. WCT showed the lowest recovery of quality

Fig. 19. Variations in the petiole colour of seedlings

No	Colour index	Colour
1.	10 GY 3/2	Dark greyish green
2.	5 GY 4/3	Moderate olive green
3.	5 Y 5/6	Light olive
4.	7.5 YR 4/5	Moderate brown
5.	5 YR 3/3	Moderate brown
6.	5 YR 4/5	Strong brown
7.	2.5 YR 5/9	Brownish orange
8.	2.5 YR 3/3	Moderate reddish brown
9.	10 YR 6/8	Dark orange yellow
10.	7.5 YR 5/7	Strong yellowish brown
11.	7.5 Y 4/3	Moderate olive
12.	2.5 Y 3/1	Brownish grey

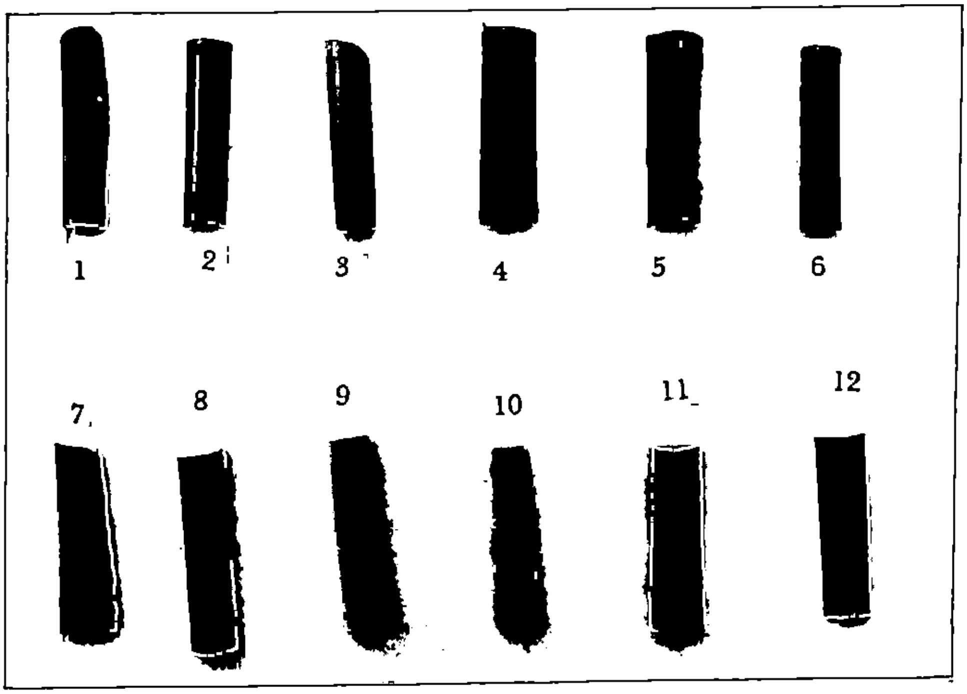


Figure 19.

Table 47. Petiole colour of seedlings - percentage of seedlings

Colour index	Colour	KI	KII	KIII	UCT	NCD
10 GY 3/2	Dark greyish green	-	-	-	7.97	-
5 GY 4/3	Moderate olive green	6.96	1.68	2.04	26.09	5.28
2.5 YR 3/3	Moderate reddish brown	0.29	3.02	0.34	0.36	3.63
2.5 YR 5/9	Brownish orange	7.54	21.14	11.56	0.36	10.56
5 YR 3/3	Moderate brown	29.86	28.52	35.03	-	22.77
5 YR 4/5	Moderate brown	17.10	25.50	26.19	-	15.84
7.5 YR 4/5	Moderate brown	27.54	16.78	20.75	-	20.13
7.5 YR 5/7	Strong yellowish brown	1.45	0.67	1.02	-	8.58
10 YR 6/8	Dark orange yellow	0.57	0.67	-	-	7.59
2.5 Y 3/1	Brownish grey	-	-	-	1.81	-
5 Y 5/6	Light olive	8.70	1.68	3.06	32.25	5.61
7.5 Y 4/3	Moderate olive	-	0.34	-	31.16	-

Table 48.

Percentage of quality seedlings to total number of seednuts

Progenies	KI	KII	KIII	WCT	NCD	Mean
1.	65.00	65.00	40.00	60.00	55.00	57.00
2.	35.00	20.00	90.00	42.50	5.00	38.50
3.	45.00	52.50	30.00	17.50	55.00	40.00
4.	77.50	67.50	77.50	72.50	52.50	69.50
5.	82.50	72.50	42.50	35.00	57.50	58.00
6.	77.50	52.50	57.50	22.50	70.00	56.00
7.	35.00	22.50	67.00	65.00	55.00	48.90
8.	57.50	72.50	40.00	47.50	40.00	51.50
9.	72.50	52.50	67.50	40.00	50.00	56.50
10.	72.50	75.00	37.50	40.00	85.00	62.00
Mean	62.00	55.25	54.95	44.25	52.50	
$F_{9,27}$	5.67**	5.56**	6.34**	3.41**	4.33**	
SE	15.07	16.88	15.74	19.10	19.81	

CD(0.05) (i) Varieties/types = 8.45
(ii) 2 progenies within same variety/type = 24.388
(iii) ,, ,, different ,, ,, = 26.528

** - Significant at 1 per cent level

seedlings (44.25 per cent) and was significantly inferior to the three Komadan groups and was on par with NCD.

4.4.8 Genetic parameters of seedling characters

Genetic parameters viz. phenotypic and genotypic coefficients of variation, heritability and genetic advance of seedling characters pertaining to five varieties/types are presented in Tables 49 to 53 and represented by bar diagrams in Figures 20 to 24.

4.4.8.1 First generation Komadan type

Phenotypic and genotypic coefficients of variation were highest for number of seedlings with split leaves (121.99 per cent and 64.94 per cent respectively). Both phenotypic and genotypic coefficients of variation were low for all other characters, the lowest values being recorded for number of leaves (7.99 per cent and 2.69 per cent respectively) . Heritability estimate was highest for days taken for germination (63.85 per cent) but the genetic advance was low (15.99 per cent). Similar trend in heritability and genetic advance was noticed for girth at collar and percentage of quality seedlings. Heritability

TABLE 49. Genetic parameters of seedling characters in KI

Sl. No.	Character	Phenotypic coefficient of variation (%)	Genotypic coefficient of variation (%)	Heritability (%)	Genetic advance (% of mean)
1	Germination percentage of seednuts	13.66	N.E	N.E	N.E
2	Days taken for germination.	12.15	9.71	63.85	15.99
3	Height of seedling	12.83	7.03	29.99	7.92
4	Number of leaves	7.99	2.69	11.38	1.87
5	Girth at collar	8.08	5.24	42.11	7.01
6	Total leaf area	22.80	7.44	10.64	5.00
7	Number of seedlings with split leaves	121.99	64.94	28.34	71.22
8	Total chlorophyll content	18.38	9.19	24.39	9.25
9	Seedling vigour index	8.19	3.27	15.91	2.68
10	Percentage of quality seedlings	35.75	26.26	53.88	39.72

N.E - Not Estimable.

and genetic advance were low for all other characters except number of seedlings with split leaves which had very high genetic advance of 71.22 per cent. Genotypic coefficient of variation, heritability and genetic advance were not estimable for germination of seednut.

4.4.8.2 Second generation Komadan type

Phenotypic and genotypic coefficients of variation were highest for number of seedlings with split leaves (94.32 per cent and 48.04 per cent respectively). Phenotypic and genotypic coefficients of variation were low for all other characters. Heritability estimate was highest for germination of seednut (64.71 per cent) with moderately high genetic advance of (43.15 per cent). Similar trend in heritability and genetic advance was noticed for percentage of quality seedlings. Heritability and genetic advance estimated for the remaining characters were low except number of seedlings with split leaves which recorded high genetic advance of 50.40 per cent. Genotypic coefficient of variation, heritability and genetic advance were not estimable for number of leaves, girth at collar and seedling vigour index in this type.

Table 50. Genetic parameters of seedling characters in KII

Sl. No.	Character	Phenotypic coefficient of variation (%)	Genotypic coefficient of variation (%)	Heritability (%)	Genetic advance (% of mean)
1.	Germination percentage of seednuts	32.37	26.04	64.71	43.15
2.	Days taken for germination	37.13	20.00	29.01	22.19
3.	Height of seedling	12.80	1.20	0.89	0.23
4.	Number of leaves	8.15	N.E	N.E	N.E
5.	Girth at collar	11.48	N.E	N.E	N.E
6.	Total leaf area	38.66	4.93	1.63	1.30
7.	Number of seedlings with split leaves	94.32	48.04	25.94	50.40
8.	Total chlorophyll content	27.11	16.52	37.09	20.69
9.	Seedling vigour index	8.41	N.E	N.E	N.E
10.	Percentage of quality seedlings	44.71	32.64	53.28	49.08

N.E - Not estimable

Fig.20. Genetic parameters of seedling characters in KI

1 - Days taken for germination

2 - Height of seedling

3 - Number of leaves

4 - Girth at collar

5 - Total leaf area

6 - Number of seedlings with split leaves

7 - Total chlorophyll content

8 - Seedling vigour index

9 - Percentage of quality seedlings

Germination percentage of seednuts - Not estimable.

Fig.21. Genetic parameters of seedling characters in KII

1 - Germination percentage of seednuts

2 - Days taken for germination

3 - Height of seedling

4 - Total leaf area

5 - Number of seedlings with split leaves

6 - Total chlorohyll content

7 - Percentage of quality seedlings

Number of leaves - Not estimable

Girth at collar - -do-

Seedling vigour index - -do-

Fig.20. Genetic parameters of seedling characters in KI

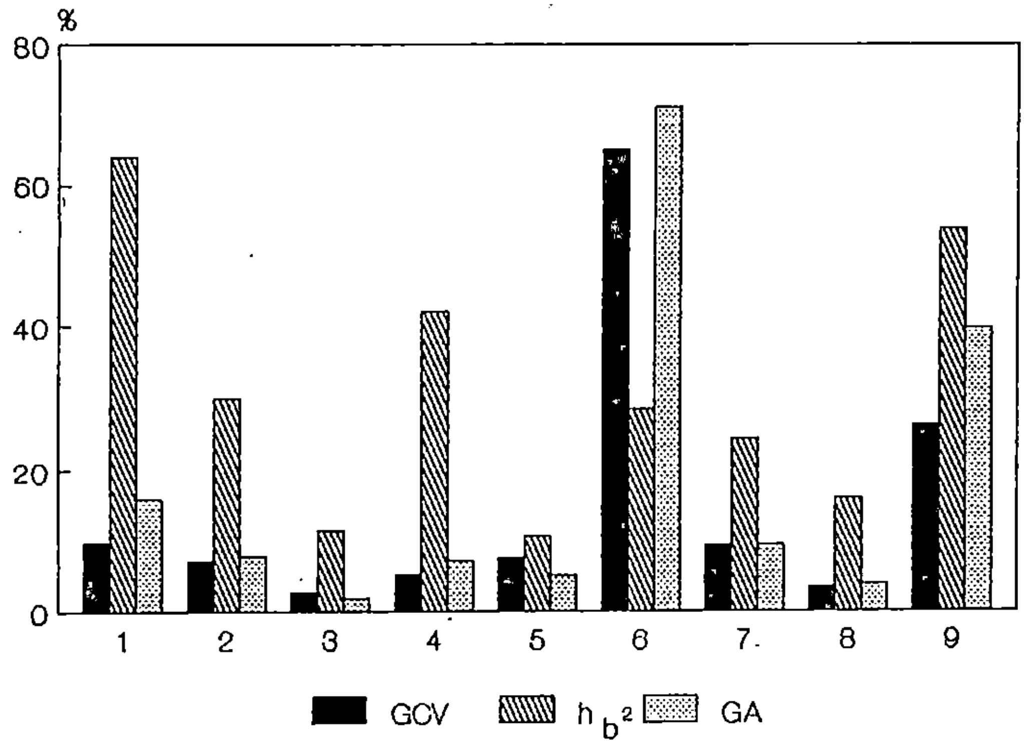
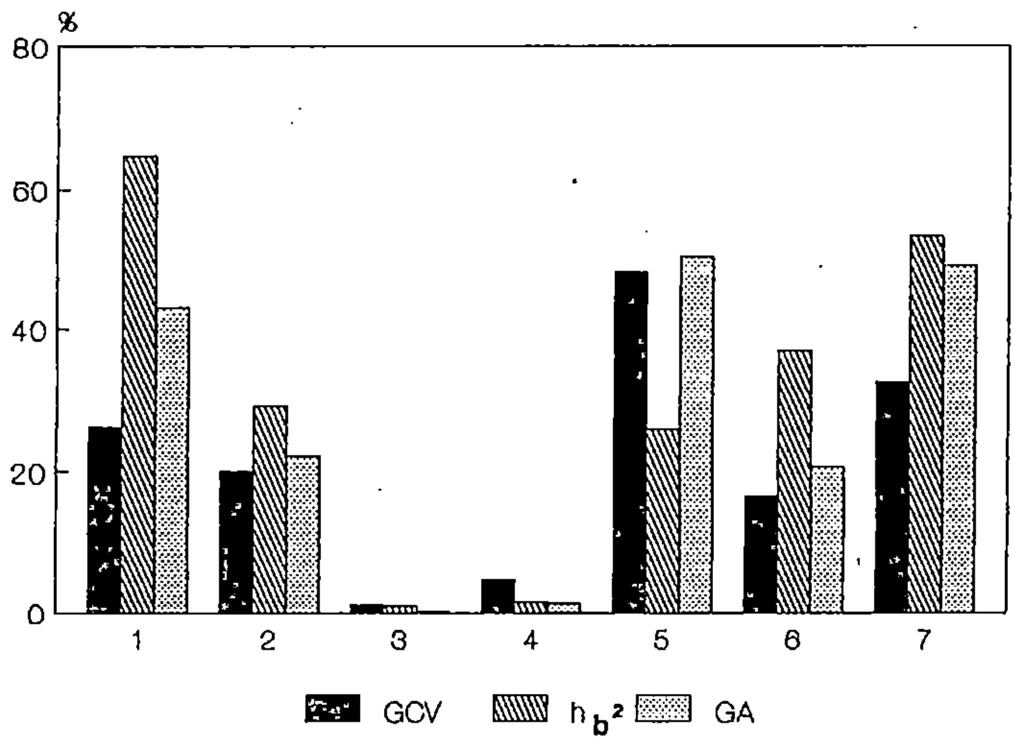


Fig.21. Genetic parameters of seedling characters in KII



4.4.8.3 Third generation Komadan type

Number of seedlings with split leaves showed the highest phenotypic as well as genotypic coefficient of variation (158.63 per cent and 114.30 per cent respectively). Moderate to high phenotypic and genotypic coefficients of variation were noticed for total leaf area, germination of seednut and percentage of quality seedlings. Number of leaves showed the lowest phenotypic and genotypic coefficients of variation (8.10 per cent and 3.46 per cent respectively). Heritability and genetic advance estimates were high for number of seedlings with split leaves and percentage of quality seedlings. Moderate to high heritability and genetic advance were observed for germination of seednuts and total leaf area. Height of seedling had high heritability (50.58 per cent) but the genetic advance was low (14.80 per cent). Similar trend in heritability and genetic advance were observed for days taken for germination and total chlorophyll content. Heritability and genetic advance were low for number of leaves and girth at collar.

Table 51. Genetic parameters of seedling characters in KIII

Sl. No.	Character	Phenotypic coefficient of variation (%)	Genotypic coefficient of variation (%)	Heritability (%)	Genetic advance (% of mean)
1.	Germination percentage of seednuts	33.14	23.38	49.79	33.98
2.	Days taken for germination	26.92	17.39	41.73	23.15
3.	Height of seedling	14.20	10.10	50.58	14.80
4.	Number of leaves	8.10	3.46	18.17	3.03
5.	Girth at collar	13.23	6.04	20.81	5.67
6.	Total leaf area	46.35	29.89	41.59	39.71
7.	Number of seedlings with split leaves	158.63	114.30	51.92	169.66
8.	Total chlorophyll content	26.74	16.46	37.62	20.73
9.	Seedling vigour index	8.82	4.34	24.23	19.35
10.	Percentage of quality seedlings	43.91	33.20	57.15	51.70

4.4.8.4. West Coast Tall variety

Number of seedlings with split leaves recorded the highest phenotypic and genotypic coefficients of variation (316.23 per cent and 86.67 per cent respectively) followed by percentage of quality seedlings and total leaf area. The other characters registered low phenotypic and genotypic coefficients of variation, the lowest value being recorded for girth at collar (7.93 per cent and 4.61 per cent respectively). Moderate to high heritability was observed for height of seedling (44.13 per cent) girth at collar (33.87 per cent) and percentage of quality seedlings (37.62 per cent) but the genetic advance was low for these characters except for quality seedlings which had high genetic advance of 42.35 per cent. Number of seedlings with split leaves had low heritability (7.41 per cent) and high genetic advance (48.25 per cent). Very low heritability and genetic advance were estimated for number of leaves and seedling vigour index. Genotypic coefficient of variation, heritability and genetic advance were not estimable for total chlorophyll content.

Table 52. Genetic parameters of seedling characters in WCT

Sl. No.	Character	Phenotypic coefficient of variation (%)	Genotypic coefficient of variation (%)	Heritability (%)	Genetic advance (% of mean)
1.	Germination percentage of seednuts	28.37	14.51	26.51	15.28
2.	Days taken for germination	16.90	7.02	17.25	6.01
3.	Height of seedling	16.57	11.00	44.13	15.06
4.	Number of leaves	12.93	3.06	5.65	1.51
5.	Girth at collar	7.93	4.61	33.87	5.53
6.	Total leaf area	38.60	18.19	22.21	17.66
7.	Number of seedlings with split leaves	316.23	86.67	7.41	48.25
8.	Total chlorophyll content	18.13	N.E	N.E	N.E
9.	Seedling vigour index	13.24	4.03	9.24	2.52
10.	Percentage of quality seedlings	54.65	33.52	37.62	42.35

N.E - Not Estimable

Fig.22. Genetic parameters of seedling characters in KIII

1 - Germination percentage of seednuts

2 - Days taken for germination

3 - Height of seedling

4 - Number of leaves

5 - Girth at collar

6 - Total leaf area

7 - Number of seedlings with split leaves

8 - Total chlorophyll content

9 - Seedling vigour index

10 - Percentage of quality seedlings

Fig.23. Genetic parameters of seedling characters in WCT

1 - Germination percentage of seednuts

2 - Days taken for germination

3 - Height of seedling

4 - Number of leaves

5 - Girth at collar

6 - Total leaf area

7 - Number of seedlings with split leaves

8 - Seedling vigour index

9 - Percentage of quality seedlings

Total chlorophyll content - not estimable

Fig.22. Genetic parameters of seedling characters in KIII

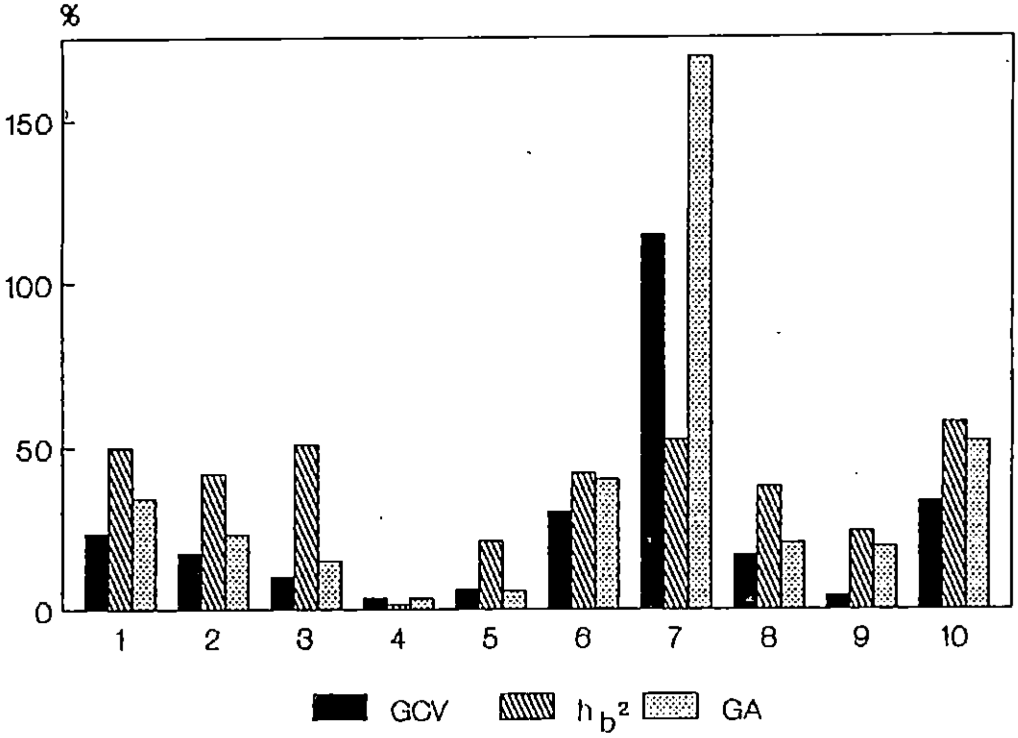
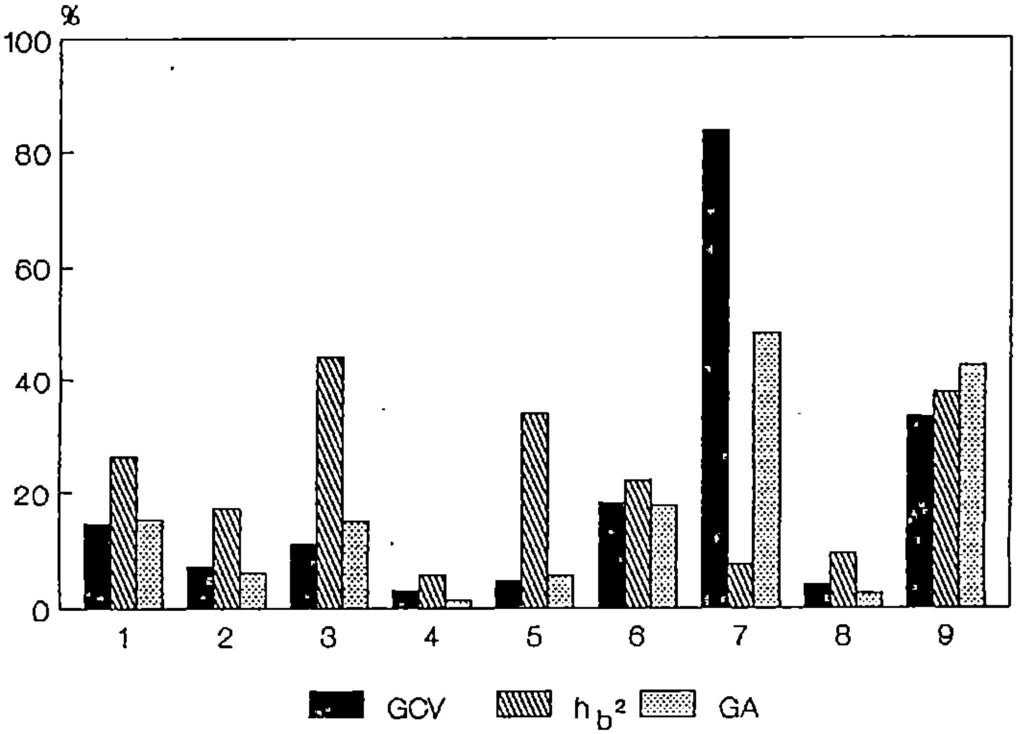


Fig.23. Genetic parameters of seedling characters in WCT



4.4.8.5 Natural Cross Dwarf type

Highest phenotypic and genotypic coefficients of variation were noticed for number of seedlings with split leaves (144.05 and 37.71 per cent respectively). Moderately high phenotypic and genotypic coefficients of variation were observed for germination of seednuts and percentage of quality seedlings. The other characters exhibited low phenotypic and genotypic coefficients of variation. High heritability and genetic advance estimates were noticed for germination of seednuts (53.40 per cent and 37.64 per cent respectively) and percentage of quality seedlings (45.43 per cent and 47.81 per cent respectively). Number of leaves, girth at collar, total chlorophyll content and seedling vigour index recorded high heritability but the genetic advance was low. The other characters exhibited low heritability and genetic advance.

4.4.9 Correlation studies on seedling characters

4.4.9.1 Phenotypic and environmental correlations among seedling characters

Tables 54 to 58 show the phenotypic and environmental correlations among seedling characters in the five varieties/types.

Table 53. Genetic parameters of seedling characters in NCD

Sl. No.	Character	Phenotypic coeficient of variation (%)	Genotypic coefficient of variation (%)	Heritability (%)	Genetic advance (% of mean)
1	Germination percentage of seednuts	34.22	25.01	53.40	37.64
2	Days taken for germination.	10.31	6.17	35.89	7.62
3	Height of Seedling	13.58	7.13	27.57	7.71
4	Number of leaves	9.80	7.69	61.44	12.41
5	Girth at collar	9.96	7.26	53.59	10.99
6	Total leaf area	26.48	9.35	12.47	6.80
7	Number of seedlings with split leaves	144.05	37.71	6.83	20.27
8	Total chlorophyll content	27.72	18.85	46.30	26.51
9	Seedling vigour index	9.97	7.88	62.48	12.84
10	Percentage of quality seedlings	51.09	34.44	45.43	47.81

Fig.24. Genetic parameters of seedling characters in NCD

1 - Germination percentage of seednuts

2 - Days taken for germination

3 - Height of seedling

4 - Number of leaves

5 - Girth at collar

6 - Total leaf area

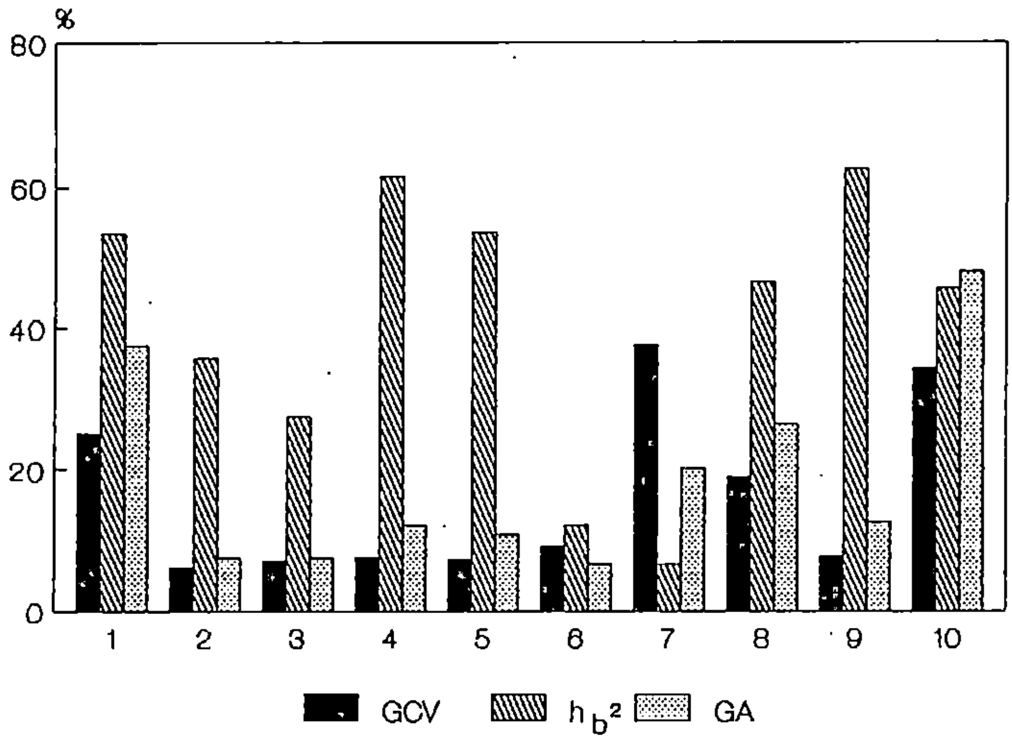
7 - Number of seedlings with split leaves

8 - Total chlorophyll content

9 - Seedling vigour index

10 - Percentage of quality seedlings

Fig.24. Genetic parameters of seedling characters in NCD



4.4.9.1.1. First generation Komadan type

Days taken for germination had shown high significant negative correlation at phenotypic level with all characters except total leaf area. Highly significant positive correlation at phenotypic level was shown by height of seedling with number of leaves and girth at collar. Number of leaves showed significant positive phenotypic correlation with girth at collar. There was only negligent level of either positive or negative correlation at phenotypic level for total leaf area with other seedling characters.

Environmental correlation for days taken for germination with height of seedling was significant and negative. Height of seedling showed significant positive correlation with all characters at environmental level. Number of leaves showed significant positive environmental correlation with girth at collar. Total leaf area showed significant positive correlation only with height of seedling at environmental level.

Table 54. Phenotypic and environmental correlation coefficients among seedling characters in KI.

	Character	x1	x2	x3	x4	x5
x1.	Days taken for germination		0.3349	-0.0957	-0.1212	0.0997
x2.	Height of seedlings	-0.5336**	----	0.6607**	0.5625**	0.3187**
x3.	Number of leaves	-0.3638**	0.6781**	----	0.3195**	0.0488
x4.	Girth at collar	-0.5773**	0.6734**	0.4245**	----	0.1946
x5.	Total leaf area	-0.1315	0.2749	0.1830	0.1208	----

Lower off triangle - Phenotypic correlation coefficient

Upper off triangle - Environmental correlation coefficient

** - Significant at 1 per cent level.

4.4.9.1.2 Second generation Komadan type

Days taken for germination showed significant negative correlation with number of leaves and girth at collar at phenotypic level. Significant positive phenotypic correlation was shown by height of seedling with number of leaves, girth at collar and total leaf area. Phenotypic correlation was high and positive for number of leaves with girth at collar and total leaf area. Total leaf area showed significant positive phenotypic correlation with all characters except days taken for germination.

Environmental correlation was significant and negative for days taken for germination with number of leaves. Height of seedling showed significant positive correlation with number of leaves, girth at collar and total leaf area at environmental level. Number of leaves showed significant positive correlation with girth at collar and total leaf area. Total leaf area showed significant positive correlation with all characters except days taken for germination at environmental level.

Table 55. Phenotypic and environmental correlation coefficients among seedling characters in KII.

	Character	x1	x2	x3	x4	x5
x1.	Days taken for germination	----	-0.2048	-0.3511*	-0.3052	0.0928
x2.	Height of seedling	-0.0440	----	0.5932**	0.6882**	0.3619*
x3.	Number of leaves	-0.4015*	0.4935**	----	0.7443**	0.3785*
x4.	Girth at collar	-0.3726*	0.6782**	0.7527**	----	0.5430**
x5.	Total leaf area	0.3024	0.3619*	0.3785*	0.4381**	----

Lower off triangle - Phenotypic correlation coefficient.

Upper off triangle - Environmental ,, ,, ,,

* - Significant at 5 per cent level.

** - Significant at 1 per cent level.

4.4.9.1.3 Third generation Komadan type

Highly significant negative correlation was shown by days taken for germination with all seedling characters at phenotypic level. Height of seedling, number of leaves, girth at collar and total leaf area showed highly significant positive correlation among themselves at phenotypic level.

Days taken for germination showed significant negative correlation with height of seedling, number of leaves and girth at collar at environmental level. Height of seedling showed high positive environmental correlation with number of leaves and girth at collar. Number of leaves and girth at collar showed significant positive correlation with total leaf area and among themselves at environmental level.

4.4.9.1.4 West Coast Tall variety

Days taken for germination showed significant negative correlation with all characters except total leaf area at phenotypic level. Highly significant positive phenotypic correlation was shown by height of seedling with number of leaves, girth at collar and total leaf area.

Table 56. Phenotypic and environmental correlation coefficients among seedling characters in KIII.

	Character	x1	x2	x3	x4	x5
x1.	Days taken for germination	----	-0.3523*	-0.4504**	-0.4866**	-0.1321
x2.	Height of seedling	-0.4997**	----	0.4728**	0.5667**	0.0036
x3.	Number of leaves	-0.6201**	0.6060**	----	0.6554**	0.3565*
x4.	Girth at collar	-0.5607**	0.7083**	0.7427**	----	0.4732**
x5.	Total leaf area	-0.3590*	0.4166**	0.4874**	0.5510**	----

Lower off triangle - Phenotypic correlation coefficient.
Upper off triangle - Environmental ,, ,, ,,

* - Significant at 5 per cent level.

** - Significant at 1 per cent level.

Phenotypic correlation for girth at collar with number of leaves and total leaf area were found to be significant and positive.

Environmental correlation was found to be significant and negative for days taken for germination with all characters except total leaf area. Height of seedling showed significant positive correlation with number of leaves and girth at collar at environmental level. Number of leaves showed high positive environmental correlation with girth at collar. Total leaf area showed no significant correlation with any of the seedling characters.

4.4.9.1.5 Natural Cross Dwarf type

Phenotypic correlation for days taken for germination was found to be significant and negative with all characters except total leaf area. Height of seedling showed significant positive phenotypic correlation with number of leaves and girth at collar. Number of leaves and girth at collar showed significant positive correlation with total leaf area and among themselves at phenotypic level.

Table 57. Phenotypic and environmental correlation coefficients among seedling characters in WCT.

	Character	x1	x2	x3	x4	x5
x1.	Days taken for germination	----	-0.4696**	-0.3352*	-0.5273**	-0.2176
x2.	Height of seedling	-0.4809**	----	0.6126**	0.7083**	0.0968
x3.	Number of leaves	-0.3953*	0.7177**	----	0.5829**	-0.1719
x4.	Girth at collar	-0.4678**	0.7132**	0.6091**	----	0.0459
x5.	Total leaf area	-0.2812	0.4217**	0.1177	0.3739*	----

Lower off triangle - Phenotypic correlation coefficient.

Upper off triangle - Environmental ,, ,, ,,

* - Significant at 5 per cent level.

** - Significant at 1 per cent level.

Table 58. Phenotypic and environmental correlation coefficients among seedling characters in NCD.

	Character	x1	x2	x3	x4	x5
x1.	Days taken for germination	----	-0.3375*	-0.0267	-0.3483*	0.2436
x2.	Height of seedling	-0.4984**	----	0.3783*	0.5941**	0.1573
x3.	Number of leaves	-0.3831*	0.4957**	----	0.4121**	0.1536
x4.	Girth at collar	-0.6368**	0.6810**	0.6546**	----	0.2243
x5.	Total leaf area	-0.0296	0.2914	0.4605**	0.3791*	----

Lower off triangle - Phenotypic correlation coefficient.

Upper off triangle - Environmental ,, ,, ,,

* - Significant at 5 per cent level.

** - Significant at 1 per cent level.

Days taken for germination showed significant negative correlation with height of seedling and girth at collar at environmental level. Significant positive environmental correlation was noticed for height of seedling with number of leaves and girth at collar. Number of leaves showed high and positive environmental correlation with girth at collar. Total leaf area showed no significant correlation with the seedling characters at environmental level.

4.4.9.2 Genotypic correlation among seedling characters

Table 59 shows the genotypic correlation coefficient among seedling characters in the five varieties/types. Days taken for germination showed negative genotypic correlation coefficient with low standard error values with the seedling characters in all the varieties/types except in second generation Komadan. The other four seedling characters viz. height of seedling, number of leaves, girth at collar and total leaf area showed relatively high positive genotypic correlation coefficients with low standard error among themselves in the five varieties/types except girth at collar with total leaf area in the first generation Komadan and number of leaves with girth at collar in the second generation Komadan.

Table 59. Genotypic correlation coefficient among seedling characters in the five varieties/types

Character	KI	KII	KIII	WCT	NCD
x_1, x_2	-0.8345 (0.0397)	2.5159 (0.9745)	-0.6762 (0.0713)	-0.5850 (0.0859)	-0.8532 (0.0358)
x_1, x_3	-1.1489 (0.0514)	N.E	-1.1224 (0.0409)	-1.0043 (0.0448)	-0.7875 (0.0497)
x_1, x_4	-1.0063 (0.0080)	N.E	-0.7811 (0.0509)	-0.3218 (0.1174)	-1.0187 (0.0110)
x_1, x_5	-0.7220 (0.0622)	3.2726 (0.9832)	-0.4866 (0.0712)	-0.5447 (0.0916)	-1.0027 (0.0206)
x_2, x_3	0.8534 (0.0377)	N.E	1.0070 (0.0147)	1.7283 (0.2818)	0.7187 (0.0633)
x_2, x_4	0.8872 (0.0282)	N.E	1.0903 (0.0308)	0.7313 (0.0609)	0.8756 (0.0307)
x_2, x_5	0.1278 (0.1280)	3.9450 (0.9881)	0.9040 (0.0241)	1.1434 (0.0458)	0.8961 (0.0298)
x_3, x_4	0.8939 (0.0297)	-0.8078 (0.0225)	1.1061 (0.0396)	1.0750 (0.0499)	0.8370 (0.0392)
x_3, x_5	1.2675 (0.0983)	N.E	0.8764 (0.0312)	2.3645 (0.6382)	1.3414 (0.1129)
x_4, x_5	-0.0903 (0.1292)	N.E	0.7787 (0.0514)	1.2432 (0.0775)	0.9133 (0.0253)

x_1 - Days taken for germination
x_2 - Height of seedling
x_3 - Number of leaves
x_4 - Girth at collar
x_5 - Total leaf area

Figures in parenthesis are standard error of genotypic correlation coefficient.

N.E - Not Estimable.

4.5 Direct and indirect effects of seednut characters on seedling vigour index.

The contributions of seednut characters on seedling vigour index through direct and indirect effects relating to five varieties /types are presented in Tables 60 to 64. The path diagram with path coefficients (direct effects) and the phenotypic correlations are presented in Figures 25 to 29. For the study of cause and effect relationship, 15 seednut characters were considered as the cause for seedling vigour index where seedling vigour index was considered as the effect.

4.5.1 First generation Komadan type

In this type husk/nut ratio had the maximum direct effect on seedling vigour index (1.903) and positive indirect effects through oil content, weight of opened nut and thickness of meat, while it had negative indirect effects on seedling vigour index through the remaining characters. The other characters which had positive direct effects on vigour index are weight of kernel (0.868), volume of nut water (0.855), weight of husked nut (0.834), weight of shell (0.828), weight of copra (0.600), thickness of husk (0.461), oil content (0.277), weight of embryo (0.084) and thickness of meat (0.056). Majority of these characters had positive indirect effects through thickness of husk, weight of husked nut, volume of nut water, thickness of meat, weight of embryo, weight of shell, weight of kernel and weight of copra. Oil content was found to exert high positive indirect effects via husk/nut ratio (0.704) and also through weight of unhusked nut, weight of opened nut and thickness of meat. The seed nut characters viz. polar and equatorial diameters of nut, weight of unhusked nut, opened nut and diameter of eye had negative direct effects on seedling vigour index, the highest effect being exerted by weight of unhusked nut (-2.381) even though the correlations between these characters and vigour index are positive. Weight of unhusked nut put forth maximum positive indirect effect on seedling vigour index through husk/nut ratio (0.942) followed by weight of husked nut and six other characters. Weight of opened nut (-0.509) was found to exert positive indirect effect on vigour index through weight of kernel (0.803) followed by weight of husked nut (0.764) and five other nut characters, while through the remaining characters the effects were negative and indirect. Diameter of eye (-0.450), equatorial diameter of nut (-0.270) and polar diameter of nut (-0.024) exerted maximum positive indirect effects through husk/nut ratio

Table 60. Direct and indirect effects of seednut characters on seedling vigour index in KI

Seednut characters	Direct effects	Indirect effects via															Total correlations
		x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13	x14	x15	
x1. Oil content	0.277	—	-0.001	-0.024	-0.035	0.216	-0.296	0.203	-0.124	0.007	-0.051	-0.019	-0.281	-0.290	-0.121	0.704	0.165
x2. Polar diameter	-0.024	0.006	—	-0.084	-0.053	-0.853	0.341	-0.188	0.270	0.012	-0.105	0.027	0.056	0.382	0.328	0.033	0.148
x3. Equaterial diameter	-0.270	0.025	-0.007	—	0.054	-1.069	0.337	-0.193	0.248	0.014	-0.197	0.007	0.077	0.380	0.325	0.370	0.101
x4. Thickness of husk	0.461	-0.021	0.003	-0.031	—	0.414	0.033	0.034	0.169	-0.010	-0.120	0.016	0.068	-0.113	-0.037	-0.605	0.361
x5. Wt. of unhusked nut	-2.381	-0.025	-0.008	-0.121	-0.080	—	0.650	-0.349	0.541	0.016	-0.356	0.034	0.411	0.539	0.393	0.942	0.206
x6. Wt. of husked nut	0.834	-0.098	-0.010	-0.109	0.018	-1.855	—	-0.467	0.643	0.013	-0.250	0.049	0.588	0.700	0.464	-0.291	0.226
x7. Wt. of opened nut	-0.509	-0.110	-0.009	-0.102	-0.031	-1.631	0.764	—	0.364	0.014	-0.171	0.044	0.570	0.803	0.500	-0.367	0.129
x8. Volume of nut water	0.855	-0.040	-0.007	-0.078	0.091	-1.507	0.628	-0.217	—	0.007	-0.282	0.037	0.384	0.263	0.226	-0.054	0.306
x9. Thickness of meat	0.056	0.037	-0.005	-0.066	-0.084	-0.680	0.195	-0.126	0.102	—	-0.081	0.011	0.076	0.235	0.254	0.314	0.238
x10. Diameter of eye	-0.450	0.031	-0.006	-0.118	0.020	-1.881	0.462	-0.194	0.535	0.010	—	0.019	0.178	0.327	0.262	0.921	0.116
x11. Wt. of embryo	0.084	-0.061	-0.008	-0.022	0.087	-0.965	0.484	-0.268	0.381	0.008	-0.099	—	0.441	0.344	0.192	-0.368	0.230
x12. Wt. of shell	0.828	-0.094	-0.002	-0.025	0.038	-1.183	0.590	-0.351	0.397	0.005	-0.097	0.045	—	0.314	0.272	-0.417	0.320
x13. Wt. of kernel	0.868	-0.093	-0.010	-0.118	-0.060	-1.478	0.673	-0.471	0.259	0.015	-0.169	0.033	0.299	—	0.501	-0.254	-0.005
x14. Wt. of copra	0.600	-0.056	-0.013	-0.146	-0.028	-1.559	0.645	-0.424	0.321	0.024	-0.196	0.027	0.375	0.724	—	-0.025	0.269
x15. Husk / nut ratio	1.903	0.102	-0.000	-0.053	-0.147	-1.178	-0.128	0.098	-0.024	0.009	-0.218	-0.016	-0.181	-0.116	-0.008	—	0.043

Residual 0.659

Fig.25. Path diagram showing the direct effects and inter relationships of seednut characters on seedling vigour index in KI.

SVI - Seedling Vigour Index.

1. Oil content

2. Polar diameter of nut

3. Equatorial diameter of nut

4. Thickness of husk

5. Weight of unhusked nut

6. Weight of husked nut

7. Weight of opened nut

8. Volume of nut water

9. Thickness of meat

10. Diameter of eye

11. Weight of embryo

12. Weight of shell

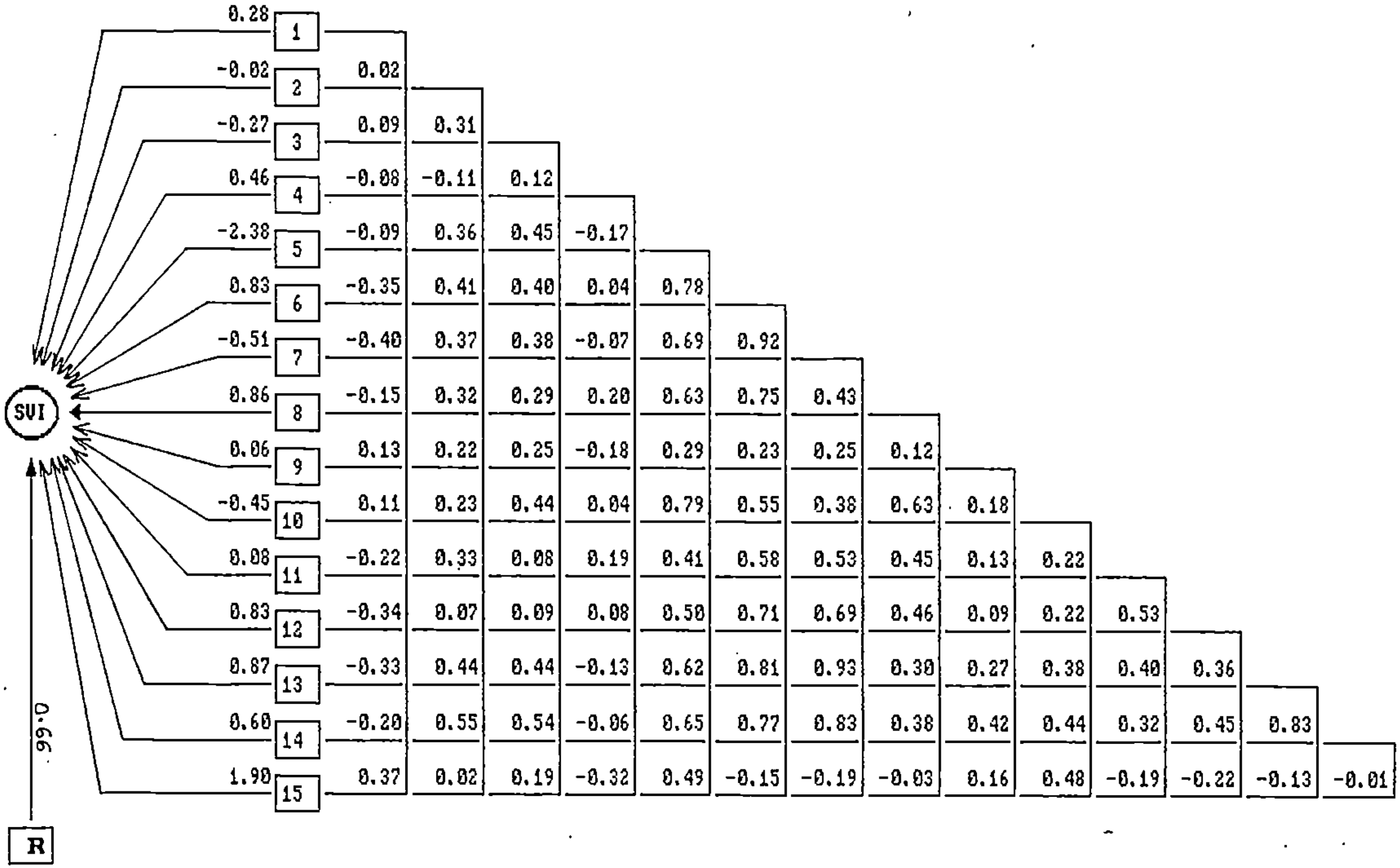
13. Weight of kernel

14. Weight of copra

15. Husk/nut ratio

R - Residual

Fig.25. Path diagram showing the direct effects and inter relationships of seednut characters on seedling vigour index in KI



Direct effects shown in arrows. Inter relationships shown in steps.

followed by various other nut characters while maximum negative indirect effects on vigour index were exerted through weight of unhusked nut followed by other characters.

4.5.2 Second generation Komadan type

Weight of husked nut had maximum direct effect on seedling vigour index (0.681). It had positive indirect effects through thickness of husk, weight of unhusked nut, volume of nut water, thickness of meat, weight of shell and kernel and negative indirect effects on vigour index through the remaining characters. Husk/nut ratio had next highest positive direct effect (0.215) on vigour index and had low positive indirect effects through oil content, thickness of husk, weight of unhusked and opened nut, diameter of eye, weight of shell and copra. It exerted negative indirect effects on vigour index through the rest of the characters. The other seednut characters which had positive direct effects on vigour index are thickness of husk (0.007), weight of unhusked nut (0.105), volume of nut water (0.053), thickness of meat (0.061), weight of shell (0.074) and kernel (0.058). These characters, in common putforth positive indirect effects on vigour index through thickness of husk, weight of unhusked and husked nuts, volume of nut water, thickness of meat, weight of shell and kernel and negative indirect effects through the remaining characters. Oil content (-0.299), polar and equatorial diameter of nut (-0.081 and -0.477 respectively), weight of opened nut (-0.245), diameter of eye (-0.227), weight of embryo (-0.348) and weight of copra (-0.060) had negative direct effects on seedling vigour index. These characters except diameter of eye putforth maximum positive indirect effect on vigour index through weight of husked nut and also through weight of unhusked nut, volume of nut water, thickness of meat, weight of shell and kernel where as diameter of eye exerted maximum positive indirect effects on vigour index via weight of embryo followed by thickness of meat, weight of husked nut, weight of kernel and volume of nut water. Majority of the seednut characters exerted negative indirect effects on vigour index through oil content, polar and equatorial diameter of nut, weight of opened nut, weight of embryo, diameter of eye and weight of copra. The correlations for most of the characters with vigour index were negative which is due to negative direct effect of the character as well as due to its negative indirect effect via a number of nut components.

Table 61. Direct and indirect effects of seednut characters on seedling vigour index in KII

Seednut characters	Direct effects	Indirect effects via															Total correlations
		x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13	x14	x15	
x1. Oil content	-0.299	—	-0.013	-0.016	0.000	0.016	0.174	-0.078	0.007	0.003	-0.007	-0.021	0.018	0.017	-0.008	-0.014	-0.221
x2. Polar diameter	-0.081	-0.049	—	-0.374	0.003	0.081	0.345	-0.146	0.017	0.018	-0.041	-0.067	0.041	0.029	-0.030	0.112	-0.142
x3. Equatorial diameter	-0.477	-0.010	-0.064	—	0.004	0.084	0.413	-0.163	0.023	0.020	-0.015	-0.017	0.051	0.028	-0.027	0.098	-0.152
x4. Thickness of husk	0.007	-0.012	-0.034	-0.282	—	0.057	0.238	-0.085	0.016	0.015	-0.006	-0.147	0.028	0.014	-0.007	0.087	-0.123
x5. Wt. of unhusked nut	0.105	-0.045	-0.063	-0.384	0.004	—	0.505	-0.178	0.035	0.017	0.002	-0.157	0.052	0.033	-0.025	0.129	0.030
x6. Wt. of husked nut	0.681	-0.077	-0.041	-0.289	0.003	0.078	—	-0.232	0.048	0.019	-0.009	-0.173	0.061	0.048	-0.038	-0.015	0.064
x7. Wt. of opened nut	-0.245	-0.095	-0.048	-0.317	0.003	0.076	0.644	—	0.039	0.020	-0.002	-0.146	0.061	0.053	-0.044	-0.015	-0.016
x8. Volume of nut water	0.053	-0.042	-0.026	-0.212	0.002	0.069	0.626	-0.182	—	0.016	-0.016	-0.180	0.051	0.035	-0.026	-0.015	0.153
x9. Thickness of meat	0.061	-0.014	-0.024	-0.155	0.002	0.029	0.217	-0.079	0.014	—	-0.130	0.052	0.016	0.019	-0.024	-0.007	-0.023
x10. Diameter of eye	-0.227	-0.010	-0.015	-0.032	0.000	-0.000	0.027	-0.002	0.004	0.035	—	0.121	-0.007	0.005	-0.014	-0.014	-0.129
x11. Wt. of embryo	-0.348	-0.018	-0.016	-0.160	0.003	0.047	0.339	-0.103	0.027	-0.009	0.079	—	0.042	0.011	0.001	0.029	-0.076
x12. Wt. of shell	0.074	-0.077	-0.045	-0.336	0.003	0.075	0.568	-0.206	0.037	0.013	0.023	-0.202	—	0.030	-0.025	0.019	-0.049
x13. Wt. of kernel	0.058	-0.089	-0.040	-0.230	0.002	0.059	0.559	-0.221	0.032	0.020	-0.021	-0.068	0.038	—	-0.049	-0.038	0.012
x14. Wt. of copra	-0.060	-0.039	-0.040	-0.212	0.001	0.044	0.436	-0.180	0.023	0.025	-0.054	0.006	0.030	0.048	—	-0.040	-0.012
x15. Husk / nut ratio	0.215	0.019	-0.042	-0.218	0.003	0.063	-0.050	0.017	-0.004	-0.002	0.015	-0.046	0.006	-0.010	0.011	—	-0.023

Residual 0.865.

Fig.26. Path diagram showing the direct effects and inter relationships of seednut characters on seedling vigour index in KII.

SVI - Seedling Vigour Index.

1. Oil content

2. Polar diameter of nut

3. Equatorial diameter of nut

4. Thickness of husk

5. Weight of unhusked nut

6. Weight of husked nut

7. Weight of opened nut

8. Volume of nut water

9. Thickness of meat

10. Diameter of eye

11. Weight of embryo

12. Weight of shell

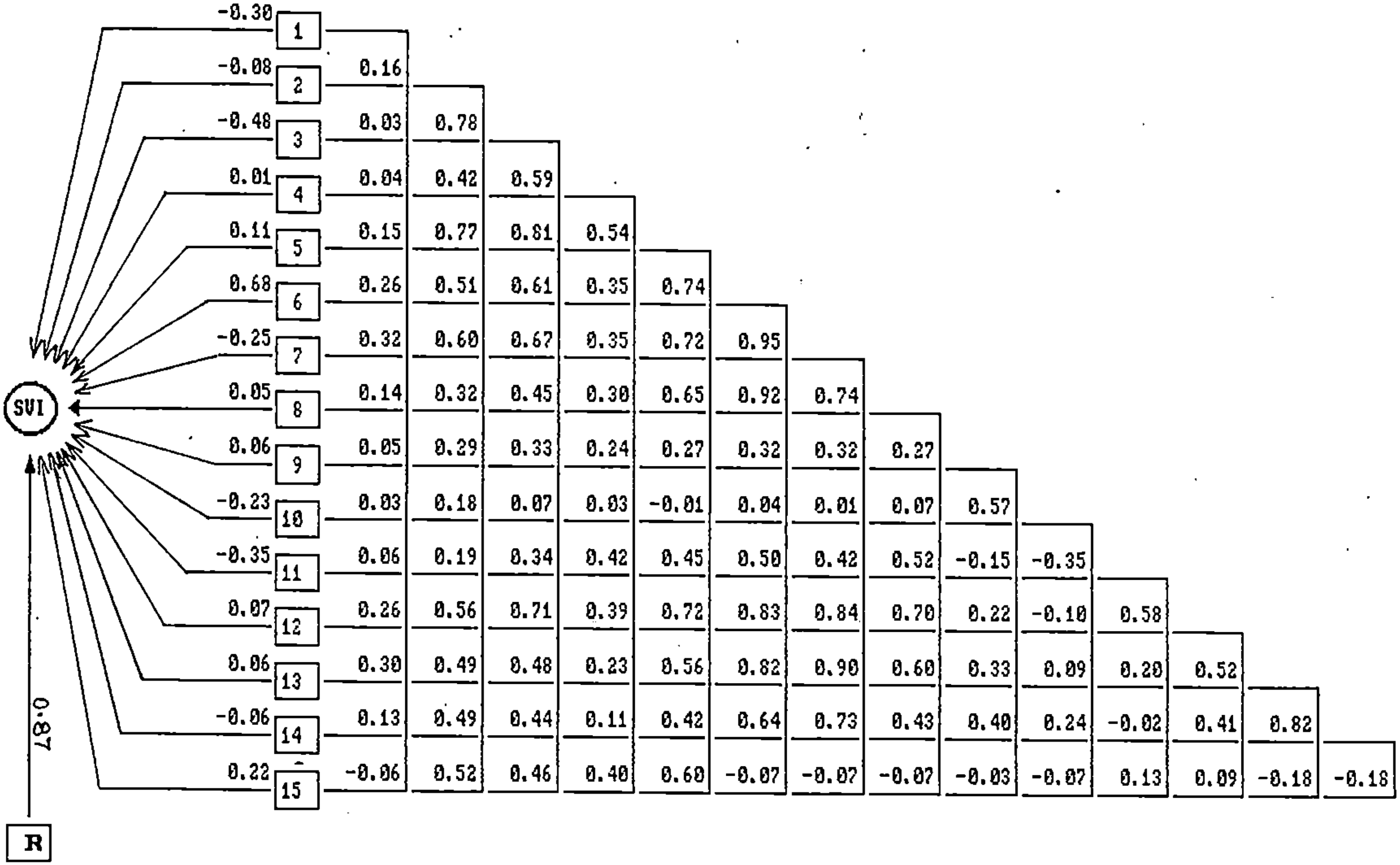
13. Weight of kernel

14. Weight of copra

15. Husk/nut ratio

R - Residual

Fig.26. Path diagram showing the direct effects and inter relationships of seednut characters on seedling vigour index in KII



Direct effects shown in arrows. Inter relationships shown in steps.

Table 62. Direct and indirect effects of seednut characters on seedling vigour index in KIII

Seednut characters	Direct effects	Indirect effects via															Total correlations
		x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13	x14	x15	
x1. Oil content	0.128	—	-0.007	0.061	0.000	0.031	0.910	-0.270	-0.240	0.168	-0.148	-0.027	0.007	0.198	-0.160	-0.283	0.368
x2. Polar diameter	0.086	-0.011	—	0.235	-0.000	-0.714	0.313	-0.070	-0.121	0.123	-0.175	-0.031	-0.006	0.008	-0.006	0.436	0.067
x3. Equatorial diameter	0.455	0.017	0.044	—	-0.000	-1.194	2.740	-0.706	-0.908	0.243	-0.376	-0.112	-0.012	0.325	-0.231	0.070	0.355
x4. Thickness of husk	-0.000	-0.009	0.021	0.243	—	-0.552	1.284	-0.408	-0.293	0.109	-0.191	-0.088	-0.017	0.163	-0.092	-0.036	0.134
x5. Wt. of unhusked nut	-1.844	-0.002	0.033	0.295	-0.000	—	3.466	-0.829	-1.256	0.159	-0.272	-0.149	-0.023	0.345	-0.144	0.443	0.222
x6. Wt. of husked nut	4.169	0.028	0.006	0.299	-0.000	-1.533	—	-1.059	-1.406	0.217	-0.315	-0.165	-0.021	0.487	-0.297	-0.046	0.364
x7. Wt. of opened nut	-1.120	0.031	0.005	0.287	-0.000	-1.366	3.944	—	-1.129	0.259	-0.354	-0.182	-0.021	0.530	-0.349	-0.143	0.392
x8. Volume of nut water	-1.536	0.020	0.007	0.269	-0.000	-1.508	3.816	-0.824	—	0.131	-0.218	-0.118	-0.019	0.360	-0.188	0.083	0.275
x9. Thickness of meat	0.429	0.050	0.025	0.257	-0.000	-0.681	2.106	-0.677	-0.469	—	-0.343	-0.079	-0.007	0.359	-0.316	-0.142	0.512
x10. Diameter of eye	-0.529	0.036	0.028	0.323	-0.000	-0.950	2.480	-0.750	-0.632	0.278	—	-0.128	-0.005	0.381	-0.283	0.008	0.257
x11. Wt. of embryo	-0.302	0.011	0.009	0.170	-0.000	-0.911	2.278	-0.676	-0.602	0.112	-0.224	—	-0.008	0.338	-0.154	0.041	0.082
x12. Wt. of shell	-0.040	-0.023	0.014	0.134	-0.000	-1.091	2.262	-0.595	-0.727	0.085	-0.075	-0.063	—	-0.179	0.096	0.120	0.084
x13. Wt. of kernel	0.554	0.046	0.001	0.267	-0.000	-1.150	3.669	-1.073	-0.998	0.279	-0.364	-0.184	-0.013	—	-0.374	-0.224	0.436
x14. Wt. of copra	-0.436	0.047	0.001	0.241	-0.000	-0.611	2.842	-0.897	-0.661	0.311	-0.343	-0.107	-0.008	0.475	—	-0.441	0.413
x15. Husk / nut ratio	0.904	-0.040	0.041	0.035	0.000	-0.904	-0.210	0.177	-0.140	-0.067	-0.004	-0.014	-0.005	-0.137	0.213	—	-0.151

Residual 0.742

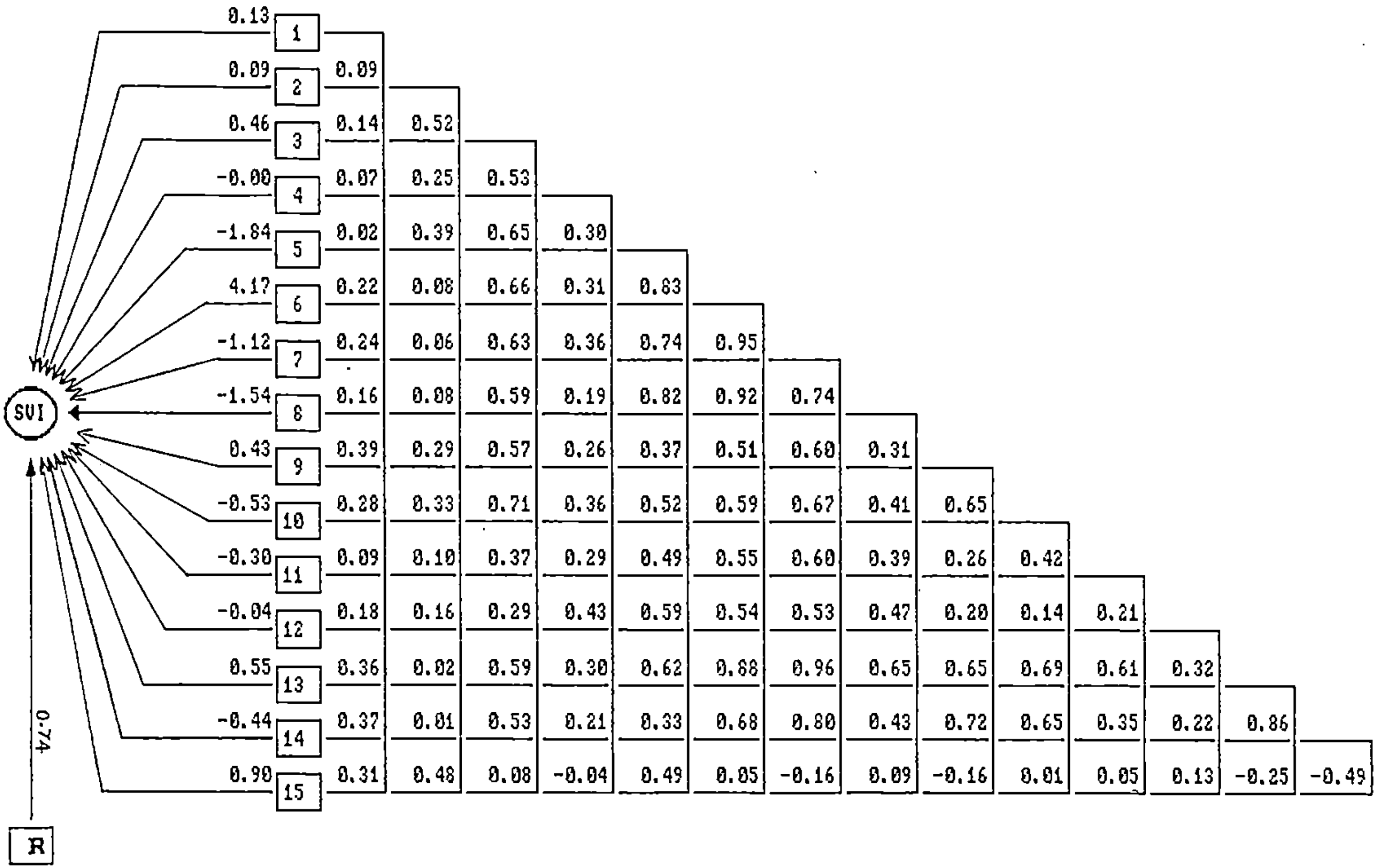
Fig.27. Path diagram showing the direct effects and inter relationships of seednut characters on seedling vigour index in KIII.

SVI - Seedling Vigour Index.

1. Oil content
2. Polar diameter of nut
3. Equatorial diameter of nut
4. Thickness of husk
5. Weight of unhusked nut
6. Weight of husked nut
7. Weight of opened nut
8. Volume of nut water
9. Thickness of meat
10. Diameter of eye
11. Weight of embryo
12. Weight of shell
13. Weight of kernel
14. Weight of copra
15. Husk/nut ratio

R - Residual

Fig.27. Path diagram showing the direct effects and inter relationships of seednut characters on seedling vigour index in KIII



Direct effects shown in arrows. Inter relationships shown in steps.

4.5.4 West Coast Tall variety

In this variety weight of opened nut had maximum direct effect on seedling vigour index (2.271), followed by weight of unhusked nut (0.954), diameter of eye (0.563) weight of copra (0.561), equatorial diameter of nut (0.321), weight of embryo (0.132) and thickness of meat (0.037). These characters exerted, in common, positive indirect effects through equatorial diameter of nut, weight of unhusked nut, weight of opened nut, thickness of meat, diameter of eye, weight of embryo and weight of copra and negative indirect effects through the remaining characters. Oil content, polar diameter of nut, thickness of husk, weight of husked nut, volume of nut water, weight of shell, kernel and husk/nut ratio exerted negative direct effects on seedling vigour index. These characters had positive indirect effects on vigour index through equatorial diameter of nut, weight of unhusked nut, weight of opened nut, thickness of meat, diameter of eye, weight of embryo and weight of copra where as oil content and husk/nut ratio exerted positive indirect effect also through polar diameter of nut. Oil content exerted negative indirect effects through thickness of meat and weight of copra also apart from the remaining characters which in common exerted negative indirect effects on vigour index.

Table 63. Direct and indirect effects of seednut characters on seedling vigour index in WCT

Seednut characters	Direct effects	Indirect effects via															Total correlations
		x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13	x14	x15	
x1. Oil content	-0.086	—	0.060	0.004	-0.079	0.171	-0.120	0.326	-0.009	-0.003	0.067	0.041	-0.086	-0.165	-0.023	-0.022	0.076
x2. Polar diameter	-0.349	0.015	—	0.175	-0.143	0.399	-0.478	1.185	-0.056	0.003	0.247	0.048	-0.104	-1.353	0.330	0.012	-0.069
x3. Equatorial diameter	0.321	-0.001	-0.191	—	-0.389	0.830	-0.802	1.967	-0.094	0.005	0.403	0.082	-0.024	-2.133	0.455	-0.080	0.169
x4. Thickness of husk	-0.556	-0.012	-0.090	0.225	—	0.711	-0.595	1.503	-0.070	0.001	0.328	0.070	-0.172	-1.590	0.269	-0.120	-0.098
x5. Wt. of unhusked nut	0.954	-0.015	-0.146	0.279	-0.414	—	-0.862	2.120	-0.105	-0.002	0.420	0.093	-0.241	-2.227	0.405	-0.118	0.141
x6. Wt. of husked nut	-0.919	-0.011	-0.182	0.280	-0.360	0.895	—	2.240	-0.113	0.005	0.439	0.095	-0.249	-2.379	0.485	-0.057	0.169
x7. Wt. of opened nut	2.271	-0.012	-0.182	0.278	-0.367	0.891	-0.906	—	-0.108	0.004	0.447	0.098	-0.253	-2.405	0.488	-0.062	0.182
x8. Volume of nut water	-0.119	-0.007	-0.162	0.251	-0.325	0.834	-0.866	2.044	—	0.009	0.413	0.087	-0.221	-2.190	0.438	-0.042	0.144
x9. Thicknes of meat	0.037	0.008	-0.032	0.042	-0.012	-0.039	-0.126	0.217	-0.028	—	-0.031	0.008	-0.014	-0.254	0.129	0.096	0.001
x10. Diameter of eye	0.563	-0.010	-0.153	0.230	-0.324	0.712	-0.717	1.806	-0.088	-0.002	—	0.101	-0.202	-1.918	0.368	-0.051	0.315
x11. Wt. of embryo	0.132	-0.026	-0.125	0.200	-0.294	0.670	-0.660	1.674	-0.078	0.002	0.429	—	-0.203	-1.705	0.312	-0.053	0.275
x12. Wt. of shell	-0.277	-0.027	-0.132	0.237	-0.346	0.834	-0.826	2.082	-0.096	0.002	0.413	0.097	—	-2.054	0.430	-0.074	0.263
x13. Wt. of kernel	-2.437	-0.006	-0.194	0.281	-0.362	0.872	-0.897	2.241	-0.108	0.004	0.443	0.093	-0.233	—	0.488	-0.054	0.131
x14. Wt. of copra	0.561	0.004	-0.205	0.260	-0.266	0.688	-0.794	1.974	-0.093	0.009	0.369	0.074	-0.212	-2.117	—	-0.016	0.236
x15. Husk / nut ratio	-0.207	-0.009	0.021	0.124	-0.323	0.545	-0.255	0.685	-0.024	-0.017	0.140	0.034	-0.098	-0.639	0.045	—	0.022

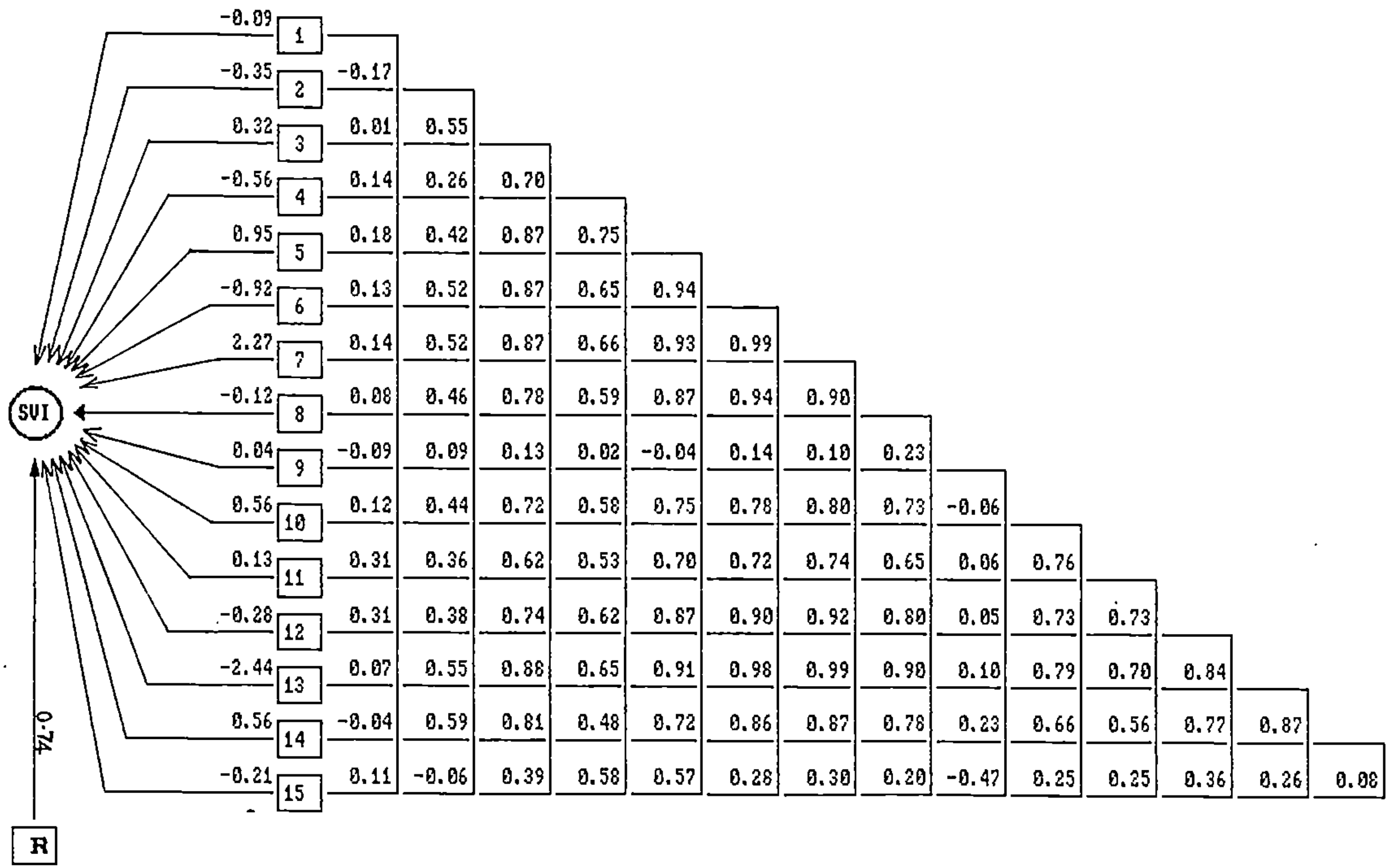
Residual 0.742

Fig.28. Path diagram showing the direct effects and inter relationships of seednut characters on seedling vigour index in WCT.

SVI	Seedling Vigour Index.
1.	Oil content
2.	Polar diameter of nut
3.	Equatorial diameter of nut
4.	Thickness of husk
5.	Weight of unhusked nut
6.	Weight of husked nut
7.	Weight of opened nut
8.	Volume of nut water
9.	Thickness of meat
10.	Diameter of eye
11.	Weight of embryo
12.	Weight of shell
13.	Weight of kernel
14.	Weight of copra
15.	Husk/nut ratio

R - Residual

Fig.28. Path diagram showing the direct effects and inter relationships of seednut characters on seedling vigour index in WCT



Direct effects shown in arrows. Inter relationships shown in steps.

4.5.5 Natural Cross Dwarf type

Weight of husked nut had the highest direct effect on seedling vigour index (7.572) in NCD type. Husk/nut ratio had the next highest direct effect (2.284) on vigour index followed by oil content (0.506), diameter of eye (0.314), weight of copra (0.246) and thickness of husk (0.079). All these characters except husk/nut ratio exerted positive indirect effects on seedling vigour index via oil content, polar diameter of nut, thickness of husk, weight of husked nut, diameter of eye and weight of copra and negative indirect effects through the remaining characters. Husk/nut ratio had positive indirect effects on vigour index through equatorial diameter of nut, weight of unhusked nut, weight of opened nut, volume of nut water, weight of embryo, shell and kernel and negative indirect effects through the rest of the characters. However, husk/nut ratio inspite of the high positive direct effect had negative correlation (-0.200) due to its high negative indirect effect through weight of husked nut. Polar and equatorial diameter of nut, weight of unhusked and opened nut, volume of nut water, thickness of meat, weight of embryo, weight of shell and weight of kernel exerted negative direct effects on seedling vigour index. All these characters except polar diameter of nut had

Table 64. Direct and indirect effects of seednut characters on seedling vigour index in NCD

Seednut characters	Direct effects	Indirect effects via															Total correlations
		x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13	x14	x15	
x1. Oil content	0.506	—	-0.049	-0.063	0.022	-0.521	1.068	-0.317	0.070	-0.060	0.082	-0.006	-0.077	-0.195	0.047	-0.119	0.388
x2. Polar diameter	-0.128	0.194	—	0.013	0.025	0.482	-2.750	0.367	0.347	-0.067	0.003	0.013	0.036	0.255	-0.055	1.198	-0.067
x3. Equatorial diameter	-0.181	0.175	0.009	—	0.029	-2.072	5.120	-0.916	-0.414	-0.023	0.178	-0.015	-0.150	-0.621	0.097	-0.955	0.261
x4. Thickness of husk	0.079	0.142	-0.040	-0.067	—	-0.149	0.595	-0.168	0.040	-0.056	0.127	0.010	-0.062	-0.047	0.051	-0.301	0.154
x5. Wt. of unhusked nut	-3.130	0.084	0.020	-0.120	0.004	—	6.824	-1.066	-0.803	-0.012	0.197	-0.032	-0.139	-0.739	0.134	-0.744	0.478
x6. Wt. of husked nut	7.572	0.071	0.046	-0.123	0.006	-2.821	—	-1.235	-0.791	0.005	0.195	-0.034	-0.174	-0.832	0.178	-1.596	0.467
x7. Wt. of opened nut	-1.346	0.119	0.035	-0.123	0.010	-2.478	6.950	—	0.414	-0.004	0.190	-0.033	-0.192	-0.905	0.205	-1.581	0.433
x8. Volume of nut water	-1.130	-0.032	0.039	-0.066	-0.003	-2.225	5.300	-0.493	—	0.018	0.119	-0.021	-0.066	-0.330	0.048	-0.848	0.310
x9. Thicknes of meat	-0.157	0.192	-0.054	-0.026	0.028	-0.247	-0.256	-0.034	0.129	—	0.094	-0.002	0.030	-0.118	0.032	0.471	0.082
x10. Diameter of eye	0.314	0.132	-0.001	-0.103	0.032	-1.966	4.714	-0.816	-0.428	-0.047	—	-0.024	-0.098	-0.586	0.102	-0.696	0.529
x11. Wt. of embryo	-0.060	0.048	0.028	-0.045	-0.013	-1.685	4.305	-0.743	-0.398	-0.005	0.125	—	-0.112	-0.490	0.105	-0.705	0.355
x12. Wt. of shell	0.263	0.149	0.018	-0.104	0.019	-1.664	5.020	-0.986	-0.288	0.018	0.117	-0.026	—	-0.462	0.154	-1.340	0.362
x13. Wt. of kernel	-0.964	0.103	0.034	-0.117	0.004	-2.400	6.531	-1.263	-0.387	-0.019	0.191	-0.030	-0.126	—	0.190	-1.380	0.367
x14. Wt. of copra	0.246	0.098	0.029	-0.071	0.017	-1.706	5.484	-1.123	-0.222	-0.020	0.130	-0.025	-0.164	-0.746	—	-1.520	0.407
x15. Husk / nut ratio	2.284	-0.026	-0.067	0.076	-0.010	1.020	-5.291	0.932	0.419	-0.032	-0.096	0.018	0.154	0.583	-0.164	—	-0.200

Residual 0.616

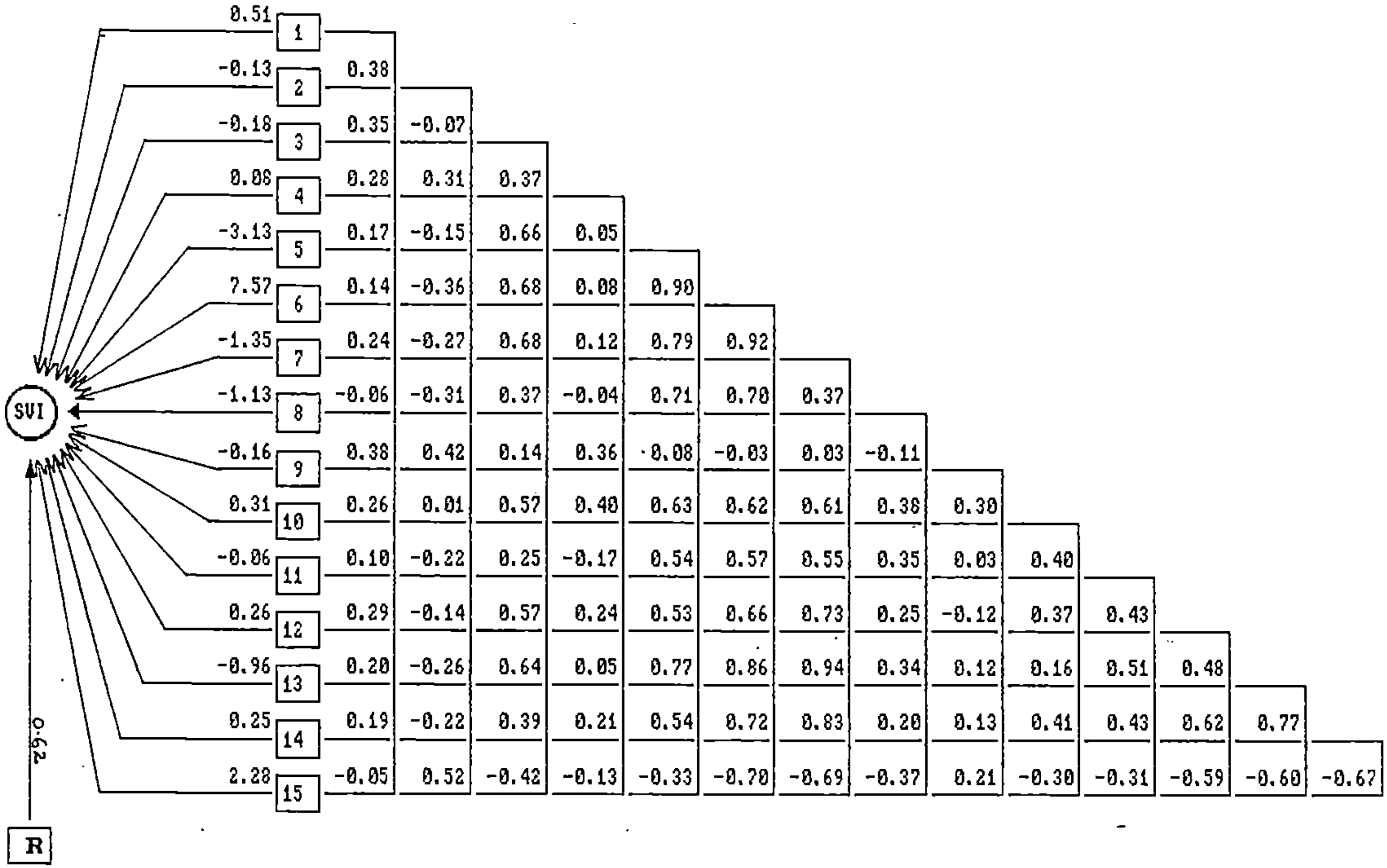
Fig.29. Path diagram showing the direct effects and inter relationships of seednut characters on seedling vigour index in NCD.

SVI - Seedling Vigour Index.

1. Oil content
2. Polar diameter of nut
3. Equatorial diameter of nut
4. Thickness of husk
5. Weight of unhusked nut
6. Weight of husked nut
7. Weight of opened nut
8. Volume of nut water
9. Thickness of meat
10. Diameter of eye
11. Weight of embryo
12. Weight of shell
13. Weight of kernel
14. Weight of copra
15. Husk/nut ratio

R - Residual

Fig.29. Path diagram showing the direct effects and inter relationships of seednut characters on seedling vigour index in NCD



Direct effects shown in arrows. Inter relationships shown in steps.

positive indirect effects on vigour index through similar characters mentioned for positive direct effect. Polar diameter of nut had negative correlation with vigour index due to its negative direct effects as well as its high negative indirect effect through weight of husked nut.

4.6 Genetic Divergence (D^2) among 50 palms in five varieties/ types.

Four seedling characters at 9^{th} month after germination viz., height of seedling, number of leaves, girth at collar and total leaf area pertaining to seedlings from 50 mother palms in the five varieties/types were subjected to D^2 analysis. The D^2 values are presented in Appendix I.

4.6.1 Group constellations: Intra and inter-cluster D^2

The clustering of the varieties/types was done by Tocher's method (Table 65) in such a way that the intra-cluster distance was small and the inter-cluster distance large. Accordingly 50 mother palms belonging to the five varieties/types were grouped into three clusters based on the seedling characters at 9^{th} month after germination.

Table 65. Mother palms included in clusters

Cluster	Mother palms
I	K_1, K_3 to K_{10}, K_{12}, K_{15}, K_{20}, K_{21}, K_{23}, K_{24}, K_{25}, K_{26}, K_{28}, K_{29}, K_{30}, W_1 to W_{10} and N_1 to N_{10}.
II	K_2, K_{11}, K_{13}, K_{14}, K_{16}, K_{17}, K_{18}, K_{19} and K_{27}.
III	K_{22}.

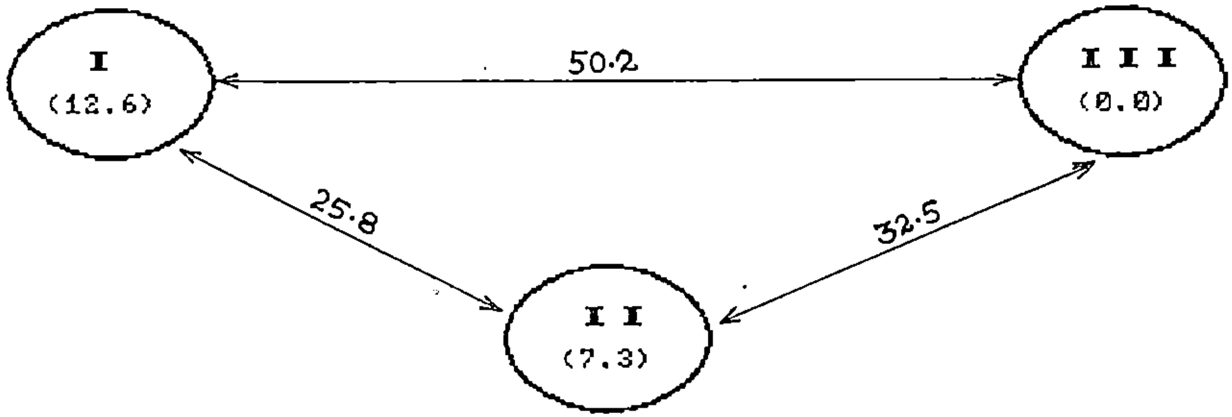
Table 66. Average intra and inter-cluster distances

(D) = ($\sqrt{D^2}$ values)

Cluster	I	II	III
I	12.62	25.82	50.23
II		7.36	32.54
III			0.00

Diagonal values are intra-cluster distances

Fig.30. Cluster diagram



Intra-cluster D values given in parenthesis
Inter-cluster D values given along the line

Among the three clusters formed cluster I included 40 palms consisting of nine palms of first generation Komadan, three palms of second generation Komadan, eight palms of third generation Komadan and all the ten palms each of WCT and NCD. Cluster II had 9 palms consisting of one palm of first generation Komadan, seven palms of second generation Komadan and one palm of third generation Komadan while cluster III was constituted by one palm belonging to the third generation Komadan.

The intra and inter-cluster D values are given in Table 66. The intra-cluster D values ranged from 0.00 to 12.62 while the inter-cluster D values ranged from 25.82 to 50.23. The maximum inter-cluster distance was displayed between groups I and III there by showing the maximum divergence. The inter-cluster distance was minimum between groups I and II. The genotypes grouped together are less divergent than the ones which fell intodifferent clusters. The inter-cluster relationships are represented diagrammatically in Figure 30, the square root of average D^2 between the clusters being used to represent the relative disposition of clusters.

DISCUSSION

5. DISCUSSION

Studies on the pattern of evolution in cultivated crop species have revealed that heritable variations occurred both before and after the beginning of cultivation. Natural hybrids recurred when such variants were grown side by side and greater number of variants resulted on which the farmers applied further selection (Allard,1960). This basic principle of crop evolution is applicable to coconut cultivation also. Whether Komadan, a group of palms grown by a cultivator in Kerala was such a cultivar or only an F_2 off type from D x T natural hybrid was the basic question put to investigation in the present study. Accordingly three generations of Komadan mother palms and their seednuts and seedlings were critically compared with those of West Coast Tall (WCT) the most prevalent tall coconut cultivar in Kerala and Natural Cross Dwarf (NCD). The mother palm, seednut and seedling characters of these five varieties/types were subjected to statistical analysis. The results obtained are discussed in the following section.

5.1 Mother palm characters

Variations were noticed among the five varieties/types for the five mother palm characters viz., number of leaves, number of bunches and spadices, number of nuts per bunch, number of female flowers per bunch and number of nuts per palm per year as evidenced by Table 3. Significant variability in mother palm characters in coconut was reported by Liyanage (1966,67), Mathew and Ramadasan (1975), Louis (1981), Gopimony (1982), Mathew et al. (1984), Ohler (1984), Nambiar and Govindan (1989) and Ramanathan (1989b). The six mother palm characters studied revealed that the three Komadan generations expressed the maximum values for most of the characters.

The first, second and third Komadan generations had more number of leaves (32.60, 34.35 and 33.75 respectively) compared to WCT (28.35). The first generation Komadan was on par with the NCD for this character. This result is in conformity with the findings of Shylaraj (1982) where the Komadan palms were reported to have around 35 fronds per palm. Increase in number of leaves is to serve advantageously in assessing the future yields as reported by Liyanage (1964).

Number of bunches and spadices was more in the three Komadan generations which were significantly superior to both WCT and NCD. A high rate of spadix production has been observed in regular bearers (Satyabalan et al.,1969). The high number of bunches produced by the first, second and third Komadan generations in the present study (14.5, 13.7 and 13.9 respectively) was more than the average figure for regular bearers (12) as pointed out by Thampan(1981) while WCT and NCD registered values lower than the average figure. Gopimony (1982) has also observed higher number of bunches in Komadan compared to WCT.

The number of unopened spadices in all the five varieties/types were on par thereby indicating no scope for selection based on this character. Number of nuts per bunch was significantly high in the first and third generation Komadan types(13.40 and 12.75 respectively) as compared to WCT and NCD. These had higher number of nuts per bunch as compared to a general average of 8.5 nuts per bunch (Nambiar, 1971 and Purseglove, 1975). The second generation Komadan was found to be on par with WCT and NCD although it registered a higher value. The superiority of Komadan over WCT for number of nuts per bunch is in conformity with the findings of Gopimony (1982).

With regard to number of female flowers per bunch, the three Komadan generations registered higher values compared to WCT and NCD, although the first generation

Selection acts on genetic differences and gains from selection for a specific character depends largely on the heritability of the character (Allard, 1960). In this study, high heritability combined with moderate to high genetic advance were recorded for nut yield per palm per year and number of female flowers per bunch. The heritability for nut yield was 58.77 percent which is in conformity with the findings of Lakshmanachar (1959), Liyanage and Sakai (1961), Nambiar and Nambiar (1970) and Meunier et al. (1984). Louis (1981) also observed moderate to high heritability and genetic advance for nut yield per palm and number of female flowers per palm. High heritability combined with moderately high genetic advance for these two characters in the present study indicate the predominance of additive genes which can be considered as a desirable feature for selection (Panse, 1957). In this context it may be pointed out that prepotency is comparable to GCA (Liyanage, 1972) and GCA in turn is governed by additive gene action which is responsible for additive genetic variation (Welsh, 1981). Thus high heritability estimates can be taken as a measure of prepotency of the palm with respect to the characters under consideration. Hence the superiority shown in these characters by the Komadan type is an indication of its genetic identity over WCT and NCD.

Komadan was significantly superior (45.15) to all other varieties/types. Peries (1934) and Liyanage (1962,91) suggested this character as reliable and important for mother palm selection. The first generation Komadan had more number of female flowers than that produced by a tall palm which varies between 20 - 40 as reported by Ohler(1984) who suggested that the great variability noticed in this character, which apart from being genetically controlled, is also strongly influenced by growing conditions.

Annual nut yield per tree is one of the most important criteria for mother palm selection (Smith,1933; Liyanage, 1962; Apacibla and Mendoza,1968; Balingasa and Caprio,1977; Chadha and Rethinam, 1989 and Ramanathan, 1989b). In the present study,the three Komadan generations were found to have a nut production potential of above 135 nuts per palm per year. This was significantly higher than that of WCT and NCD, the lowest being noticed for WCT. This is in agreement with the findings of Gopimony (1982) where more than 99% of Komadan palms gave more than 80 nuts per tree per year, while the average yield of WCT was comparatively less. The first generation Komadan was found to produce more than three times the general average of 60 nuts per palm per year (Liyanage, 1966) and about five times the general average of 40 nuts per palm per year (Ohler, 1984) thereby showing the very high yield potential of Komadan type. The second and third generation Komadan also expressed their high production potential compared to NCD and WCT. This character is controlled by additive genetic variation (Nambiar and Nambiar, 1970) and that non-additive gene action was low and selection practised for this character might be indirectly based on component characters (Ohler, 1984).

In general, it can be noticed that with regard to all mother palm characters studied, Komadan types exhibited their superiority over WCT and NCD except in number of unopened spadices where all the varieties/types were on par. The superiority of Komadan over WCT was reported earlier by Gopimony (1982) and Shylaraj (1982).

5.1.1 Genetic parameters of mother palm characters.

Selection of mother palm could be done only if there is genetic variation. The variability available in a population could be partitioned into heritable and non-heritable components; using the genetic parameters phenotypic coefficient of variation, genotypic coefficient of variation, heritability and genetic advance; based on which selection can be effectively carried out. The phenotypic coefficient of variation gives a measure of total variability. The genotypic coefficient of variation helps to compare and assess the range of genetic diversity for quantitative characters. In the present study, the phenotypic coefficient of variation was higher than genotypic coefficient of variation for all characters as seen from Table 4 indicating the influence of environment on the genotype for the expression of the character. A medium to high phenotypic and genotypic coefficients of variation were observed for number of nuts per palm per year, number of female flowers per bunch and number of nuts per bunch. Similar results have been reported by Bourdeix et al. (1991a) and Ovasuru et al. (1991). This shows that improvement through mother palm selection can be effective, provided selection is done for these three characters since there is considerable extent of genetic variability available. The present findings corroborate the earlier reports of Louis (1981). The very low variability (both phenotypic and genotypic coefficients of variation) noticed for number of leaves indicate the difficulty in improving this character by selection.

5.1.2 Correlation studies on mother palm characters.

Correlation provides information on the nature and extent of relationship among the various characters. The simple correlation which implies phenotypic correlation in the present study serves the purpose of orientation rather than prediction (Table 5). In WCT, all the characters except number of leaves showed significant positive correlation with nut yield. Similar correlations were observed in coconut by Nampoothiri et al. (1975) and Sukumaran et al. (1981). The correlations noticed in second generation Komadan type imply a higher setting percentage of female flowers which lead to more number of nuts per bunch and ultimately the yield. However, in WCT, the yield increase was not particularly due to the setting percentage of female flowers alone but number of bunches and spadices also contributed to yield increase.

The correlation coefficients estimated over the five varieties/types showed number of leaves to be significantly and positively correlated with number of bunches. This is in agreement with the findings of Menon and Pandalai (1958), Mathew et al. (1984) and Mathew and Gopimony (1991a). This correlation reveals that almost every leaf axil has a bunch in it and when the number of leaves are more in a palm there will be a corresponding increase in number of bunches also which ultimately leads to increase in nut yield (Nambiar and Govindan, 1989 ; Balakrishnan *et al*., 1991; Narayanankutty and Gopalakrishnan, 1991). Significant positive correlations were noticed for number of bunches and spadices with number of nuts per bunch, number of female flowers per bunch and number of nuts per palm per year over the five varieties /types . This is in conformity with the findings of Nampoothiri *et al*. (1975); Sukumaran *et al.* (1981) and Kalathiya and Sen (1991).

In general, the correlation studies among mother palm characters have not shown any distinct pattern for the Komadan types compared to WCT and NCD except the fact that the second generation Komadan alone has shown significant positive correlation individually for number of bunches and spadices with number of nuts per bunch, number of female flowers per bunch and number of nuts per palm per year.

5.1.3 Pollination system and bearing habit of mother palms

When the Komadan palms in the three generations were considered together, 33 per cent of them showed self pollinating nature expressed by the absence of interphase in anthesis. The second and third generations had more number of self pollinating palms compared to the first generation type. Gopimony(1982) also reported on the self pollinating nature of Komadan and opined that it is advantageous in transmitting the high yielding characters to its progenies. In the present study, WCT was found to be highly cross pollinated and NCD highly self pollinated. Similar finding has been reported by Pillai et al. (1991) and they suggested that this trait is useful in the identification of cultivars. This shows that the Komadan types occupy a position in between the NCD and WCT regarding the pollination system since 33 per cent of the Komadan palms are self pollinated.

In order to assess the bearing habit of mother palms, yield of nuts were recorded for two consecutive years and it was seen that (Table 5) in the first, second and third generations of Komadan, one, three and two palms respectively were intermediate in bearing habit, in the second generation three palms showed alternate bearing habit. In all these cases, spadices were formed in the leaf axil but the number of female flowers ranged from very few to nil as against the findings of Nambiar and Govindan (1989) who reported that when every leaf produces an inflorescence in the axil, the palm is considered to be a regular bearer. In the present study, four WCT palms were found to be regular bearers while the remaining wore intermediate. Nambiar and Govindan (1989) have reported that only 34 per cent of WCT palms were regular bearers. All the NCD palms except one were seen to have alternate bearing nature of varying degrees. This is expected since the female parent of this type is known for alternate bearing habit.

5.1.4 Pigmentation on leaf stalk in mother palms.

From Table 7 it is seen that about 90 per cent of the palms in all the five varieties /types exhibited olive shade for the leaf stalk while only 10 per cent of the palms showed any variation for this character. NCD palms also showed the dominant olive shade of the tall palms which contributed the male gametes for its production (Whitehead, et al .1966). In general, not much variability was noticed for leaf stalk colour of mother palms and that this character cannot be considered as additional character for exercising selection of mother palms.

5.1.5 Pigmentation on nut in mother palms

The nut colour variation is presented in Table 8. All the palms under the three Komadan groups had nuts of different shades of brown colour viz., moderate olive brown, moderate brown and greyish brown. Lamothe and Rognon (1977) have called these brown while Harries (1976) mentioned it as bronze. Bronze colour was reported to be the product of hybridisation between green and red or orange palms homozygous for these colours (Anonymous, 1966; Lamothe and Rognon, 1977). In WCT, different shades of green nuts were noticed in 70 per cent of the palms while the remaining palms had different shades of olive and brown nuts. NCD type had varying shades of green, olive and brown nuts which may be the result of segregation of genes for nut colour.

The present study on nut colour of the mother palms clearly indicates the distinction of Komadan as a separate group against WCT and NCD. In this connection, if we correlate this character with high nut yield per palm per year as shown by the Komadan group it will help to check the finding of Child (1964) that high yielding palms produce more brown nuts than green ones.

5.2 Seednut characters

The seednut characters provide a reliable estimate for exercising selection because they are more or less stable throughout the stabilised yield period (Rao and Pillai, 1982). In the present study,15 seednut characters were considered to determine the genetic status of Komadan in relation to WCT and NCD. These seednut characters showed significant difference among the five varieties/types as against the findings of Ramanathan and Nallathambi (1988). The Komadan types were significantly superior to WCT in all characters except oil content, thickness of husk and husk/nut ratio (Table 9.). In most of these characters, NCD was found to be on par with Komadan. However, the maximum values were always expressed by Komadan types. The NCD type being a hybrid expresses its superiority due to hybrid vigour. The Komadan types were better than or equally good to these hybrids in seednut characters but definitely superior to WCT. For thickness of meat,the three Komadan generations behaved as a distinct type and showed significant superiority over NCD and WCT. This character might have influenced the increase in kernel and copra weights of Komadan considerably.

Selection pressure is always directed towards bigger nuts with lesser husk (Rao and Pillai, 1982; Liyanage and Abeywardena, 1985). The percentage of husk was plotted against the weight of unhusked nut and the scatter diagram is given in Figure 11. The diagram shows that the WCT variety fell into a group with nuts having 51-67 per cent husk and weighing 416-1340 g. These parameters match closely to those of the primitive Niu kafa type. The NCD type with a husk percentage ranging from 25 to 40 and nut weight from 688-977 g fell closely towards the highly evolved Niu vai type. With regard to the three generations of Komadan, those from the centre of origin have 31 to 48 per cent husk and 720 to 1118 g unhusked nut weight. The other two generations have almost similar values ranging from 38 to 62 per cent of husk and unhusked nut weight ranging from 855 to 1772 g there by accomodating the three generations of Komadan in an area midway between NCD and WCT with a clear progression through generations towards better weight of unhusked nut.

With regard to the equatorial diameter of nut, the Komadan and NCD types were on par and significantly superior to WCT. Variability in equatorial diameter of nut has been reported by Foale (1987). Higher equatorial diameter of nut is reported to be an indication of high copra content (Balakrishnan and Vijayakumar, 1988). This prediction has been proved in the present study also as both Komadan and NCD have registered significantly higher copra content when compared to WCT. Variability in copra content has been reported by Santos et al. (1981), Bavappa and Sukumaran (1983), Rajamony et al. (1983) and Lamothe and Benard (1985).

The oil content in Komadan types were on par with WCT and these were significantly superior to NCD. This is in agreement with the findings of Louis and Ramachandran (1981) who have reported that the oil content in tall varieties was higher than that in the hybrids.

The three Komadan generations were significantly superior to WCT in all seednut characters except polar diameter of nut, oil content, thickness of husk and husk/nut ratio where as NCD was found to be on par with most of the seed nut characters. However, the Komadan type maintained its genetic identity over generations in several seednut characters viz., equatorial diameter of nut, thickness of husk, weight of unhusked nut, weight of husked nut, volume of nut water, thickness of meat, diameter of eye, weight of embryo, weight of kernel, weight of copra and oil content.

The fruit component analysis of the five coconut types/varieties has clearly indicated the probable origin of Komadan from the NCD segregants at the centre of origin through discrete selections done by the coconut farmers based on phenotypic characters like larger bunches and fruits of bronze colour with thicker kernel and better copra content. The difference among the three generations of Komadan in some of the fruit component characters indicate that the history of artificial selection done on this coconut type was probably very short and the scope for selection was not yet fully exploited . The first lot of 50 Komadan seedlings brought from the centre of origin to the Instructional Farm, College of Agriculture, Vellayani during 1957 on the initiative of the then Farm Superintendent were probably a random sample of the type available there. It is unlikely that strict procedure of selection was followed and later these were used for the distribution of Komadan seedlings from the Instructional Farm to farmers. The third generation Komadan palms have originated as a result of scientific three tier selections done at mother palm, seednut and seedling stages on the second generation Komadan palms available at Vellayani.

5.2.1 Genetic parameters of seednut characters

A moderate to high phenotypic and genotypic coefficients of variation obtained for volume of nut water, weight of unhusked nut, husked nut, shell, kernel and copra give an indication of the genetic variability for these characters (Table 10). This offers scope for formulating selection procedures on the basis of these characters.

The high heritability and genetic advance noticed in the present study for husk/nut ratio, weight of husked nut , opened nut embryo, shell, kernel and copra gives an indication of the extent of genetic control involved in the expression of these characters. The same view was reported by Liyanage and Sakai (1961), Mathew (1983), Meunier et al. (1984), Liyanage (1991) and Mathew and Gopimony (1991a).

5.2.2 Correlation among seednut characters

The relationships among the seednut characters in each variety/type as seen from Tables 11 to 15 have shown that the economically important characters viz., kernel and copra were positively influenced by most of the seednut characters except thickness of husk and husk/nut ratio in the Komadan types. Similar trend was seen in NCD also. But in WCT, the thickness of husk was found to be positively correlated with kernel and copra content. However, thickness of meat, for which the Komadan types were distinctly superior to WCT and NCD, was found to show significant positive correlation with kernel and copra content in Komadan types. This type of correlation was absent in WCT and NCD. Oil content in all the five varieties/types were found to be either uncorrelated or negatively correlated with majority of seednut characters. In all the varieties/types, the weight of opened nut, weight of kernel and weight of husked nut have shown very high positive correlations among themselves. Similar correlations among seednut characters were reported earlier by Mathew (1983), Satyabalan and Mathew (1984) and Balakrishnan and Vijayakumar (1988).

5.3 Embryo and kernel weights of open pollinated and selfed nuts

Selfing was carried out in all the palms belonging to the five varieties/types inorder to identify promising genotypes by studying the inbreeding depression on embryo and kernel weight of nuts. Another objective of this study was to assess the level of homozygosity achieved by the

Komadan types through natural self-pollination prevalent in that type. It was Liyanage (1967) who suggested this procedure for the assessment of inbreeding depression in coconut types.

A perusal of Tables 16 and 17 will show that the three Komadan generations have behaved as a distinct group against WCT and NCD types for this character. There was significant reduction in embryo and kernel weight in the selfed nuts of NCD and WCT (Table 18) indicating a high degree of inbreeding depression. This indirectly shows the heterozygous nature of these genotypes. Inbreeding depression in coconut has been reported earlier by Harland (1957), Haldane (1958), Menon and Pandalai (1958), and Liyanage (1967,69), Bordeuix (1988), Nambiar and Govindan,(1989), Bourdeix et al. (1991a), Nair and Balakrishnan (1991) and Nair et al. (1991). Bordeuix (1988) stated that inbreeding depression was accompanied by a reduction in chiasma frequency which corresponds to a reduction in recombination frequency. In the case of Komadan types, there was either insignificant reduction in the weight of embryo or a significant increase in the weight of kernel in the selfed nuts when compared to open pollinated ones. This result indicates the high degree of homozygosity achieved by the Komadan types through natural self pollination. In this character, the WCT and NCD were showing a diametrically opposed behaviour pattern. These findings clearly show the high level of genetic stability achieved by the Komadan group through generations of artificial selection by farmers and its subsequent adaptation for self pollination.

5.4 Seedling characters

5.4.1 Germination of seednuts

Early germination of seednuts in coconut was associated with early bearing and increased nut yield by many workers (Jack and Sands, 1929; Liyanage and Sakai, 1961; Harries, 1982 ; Satyabalan , 1984 d). In the present study, the second and third generation Komadan types have shown significant early germination when compared to all other varieties/types (Table 21). But in the final germination percentage, first generation Komadan type has shown significantly higher values over all other varieties/types (Table 20). Variation in germination percentage has been reported earlier in coconut varieties by Silva and George (1970), Ninan(1978) and Anil Kumar and Pillai (1989). The first generation Komadan, WCT and NCD were found to be late germinating varieties/types but the first generation Komadan has surpassed the second and third generation Komadans in germination percentage after six months of growing. Similar observation was reported by AnilKumar and Pillai (1989) in their germination studies on Komadan and WCT seednuts.

5.4.2 Seedling characters at different stages of growth

Seedling selection is the third stage of the three tier selection procedure followed in the production of quality seedlings in coconuts. The effectiveness of selection based on seedling characters for genetic improvement of coconut was reported by Fremond et al.(1966), Apacibla and Mendoza (1968), Silva and George (1970), Kannan and Nambiar (1979) and Shylaraj (1982).

In the present study, five characters namely height, number of leaves, girth at collar, total leaf area and chlorophyll content were observed both at 5th and 9th month after germination (Table 22 to 36). The fifth month observations were done based on the reported efficacy of early selection by Satyabalan and Mathew (1977). On the basis of 9th month observations, the seedling vigour index was computed and compared. Since the experimental seedlings were sold out to farmers at 12^{th} month after sowing a final observation on height , number of leaves, girth at collar and number of split leaves was also made and subjected to analysis. The growth increment from 5^{th} to 9^{th} month after germination was also measured and analysed. The salient features of these results are discussed below.

In all the characters observed on seedlings at various stages of growth, the Komadan group has shown significantly superior values over that of WCT except in the case of chlorophyll content at 5^{th} month and chlorophyll `b' at $9^{th}$ month. NCD was found to be on par with WCT for total leaf area at 5th month, height, total leaf area, chlorophyll `a' and total chlorophyll at 9^{th} month and number of split leaves at 12^{th} month. For all other characters,NCD was on par with one or more of the three Komadan types. But Komadan as a single group has shown definite superiority over WCT in all the characters studied on seedlings except those mentioned above. Both at 5^{th} and 9^{th} months after germination, Komadan types have behaved as a distinct group with regard to total leaf area over both WCT and NCD. Mathes <u>et al.</u>(1989) have reported the importance of total leaf area as the character which determines the total biological productivity through photosynthesis. Komadan as a group has excelled in this character over WCT and NCD. In seedling vigour index computed on the basis of days taken for germination, height, number of leaves, girth at collar and total leaf area at 9th month after germination (Table 34), the Komadan group was found significantly superior over WCT. This is in agreement with the findings of Rathinakumar et al . (1991) where the above mentioned seedling characters were reported to have contributed to high index score even at 4th month of growth. However NCD was found on par with the third generation Komadan in this character.

The observations on growth increment of seedlings from 5th to 9th month after germination have a special significance in coconut nursery management since the plants become fully dependent on photosynthetic efficiency for nutrition for the first time during this period after sowing (Foale, 1968 and Satyabalan 1984b). The Komadan group has shown significant superiority over WCT in leaf production, the critical character that determines the photosynthetic efficiency. The second generation Komadan has shown significant superiority in total increment of leaf area during this period over all other varieties/types.

Observations on height, number of leaves, girth at collar and number of seedlings with split leaves at 12th

month after sowing have also shown significant superiority of the Komadan types over WCT (Table 43 to 46). In number of seedlings with split leaves, all the three Komadan types have shown significant superiority over both WCT and NCD which were found to be on par for that character. The usefulness of selecting seedlings based on height, leaf production, girth at collar, total leaf area and split leaf Production for the genetic upgrading of coconuts has been emphasised by many workers like Menon and Pandalai (1958), Marar (1960), Srinivasa and Ramu (1971), Shylaraj (1982), Satyabalan (1984 d), Mathew et al. (1984) and Mathes et al. (1989). So the constant superior expressions of many seedling characters by the Komadan group indicate its genetic superiority over WCT. This was further proved in Table 48 which shows the recovery of quality seedlings over the number of seednuts originally sown. In this character, the Komadan group has again shown its superiority over both WCT and NCD. All the three generations of Komadan were found to be on par regarding in this character. As per package of practices recommendations the maximum recovery of quality seedlings from seednuts sown is fixed as 60 to 65 per cent (Anonymous, 1989). If we consider mother palms which produce a minimum of 65 per cent quality seedlings as prepotent ones, while only 20 per cent of such palms were found in both WCT and NCD groups, 40 to 60 per cent such prepotent palms were present in the Komadan group (Table 47). Presence of such prepotent mother palms among coconut varieties was reported by Harland (1957), Ninan and Pankajakshan (1961), Liyanage (1967), Nampoothiri et al. (1975), Gopimony (1982), Mathew et al. (1984), Satyabalan and Rajagopal (1985) and Ramanathan (1989b).

5.4.3 Petiole colour of seedlings

Association of copper colours of leaf stalk among the seedlings originated from open-pollinated seednuts of dwarf orange coconut varieties with hybrid vigour and consequent high yield is known even to the farmers of Kerala (Anonymous, 1966). Hence a petiole (leaf stalk) colour analysis of the seedling progenies of the five coconut varieties/types in the present study has great relevance in identifying the genetic origin of Komadan types. The results presented in Table 47 have shown that 71 to 82 per cent of seedlings among the three Komadan types have shown moderate brown colour while the rest were moderate olive green, strong yellowish brown or dark orange yellow. These shades are similar to those expressed by the terms orange and brown by Lamothe and Rognon (1977) and bronze by Harries (1976) to denote the typical vigorous naturally occurring off types by open pollination of dwarf orange palms through pollination from tall palms. The NCD progenies have shown wider variation in the petiole colour as predicted by Whitehead et al. (1966). More than 97 per cent of WCT seedlings have shown different shades of green and olive green.

Since we have already established the strong association of Komadan group with high productivity through the mother palm and seednut analysis in earlier sections, the present results on petiole colour indicate the possibility of inclusion of one more character namely bronze petiole colour in the selection of quality seedlings in coconut. This suggestion is in conformity with similar recommendations of Rognon (1972). The wide spread association of bronze colour with the petiole of Komadan seedlings found in the present study irrevocably proves the genetic origin of Komadan from NCD and its stabilization through earlier generations of selection by farmers and the last two generations by scientists of Kerala Agricultural University.

5.4.4 Genetic parameters of seedling characters

Genetic parameters of seedling characters viz., phenotypic and genotypic coefficients of variation, heritability and genetic advance were estimated in the five varieties/types. Phenotypic and genotypic coefficients of variations estimates computed for seedling characters gave an idea of the amount of genetic variability between seedlings of different mother palms in each variety/type. Perusal of Tables 49 to 53 shows that in all the five varieties/types phenotypic and genotypic coefficients of variation values were high for number of seedlings with split leaves. This finding is in agreement with that of Mathew (1983). Moderate values for phenotypic and genotypic coefficients of variation were noticed for germination aspects and percentage of quality seedlings in the three Komadan generations and NCD while in WCT only percentage of quality seedlings exhibited moderate values. These characters which showed moderate to high genotypic coefficient of variation indicated that they are less susceptible to random environment. Girth at Collar which was reported to be an important criterion in seedling selection (Menon and Pandalai, 1958 ; Pankajakshan and George, 1961; Nampoothiri et al., 1975; Ramadasan et al.;

1985) failed to show high coefficient of variation among the seedlings of different palms in the varieties/types. This is in agreement with the findings of Mathew (1983). However, in the three Komadan types, the coefficient of variation was lowest for number of leaves while in WCT it was lowest for girth at collar and for NCD it was lowest for number of leaves as well as girth at collar. These findings indirectly contribute towards the separate origin hypothesis of Komadan.

In all the three Komadan types and NCD, heritability and genetic advance were moderate to high for germination of seednuts and percentage of quality seedlings indicating the predominance of additive genes, while number of seedlings with split leaves had very high genetic advance with low heritability. This shows that the effect of environment is comparatively less for germination of seednuts and percentage of quality seedlings and that selection on the basis of these characters in Komadan will result in seedlings with better height, girth and number of leaves. However in WCT, germination of seednuts had low heritability and genetic advance indicating that selection on the basis this character is not effective in WCT as against the findings of Mathew (1983) in WCT. Inspite of moderate to high heritability for girth at collar in all varieties/types, the genetic advance was low for it indicating the influence of non-additive gene action. This result is in conformity with that of Louis (1981).

5.4.5 Correlation studies on seedling characters

A perusal of Tables 54 to 58 showed that days taken for germination had significant negative correlation at phenotypic level with most of the seedling characters in all the five varieties/types indicating that early germinating seednuts produced taller seedlings with more number of leaves and increased girth at collar. In the Komadan types, except in the first generation, height of seedling, number of leaves, girth at collar and total leaf area were found to be significantly and positively correlated among themselves. Similar correlations were reported by Pankajakshan and George (1961) and Sreerangasamy and Sridharan (1991). Girth at collar which is an important criterion in seedling selection has been found to be positively correlated with all other characters indicating its relevance in seedling selection. This is in conformity with the results of Nampoothiri et al. (1975) and Valsala and Kannan (1990). In the third generation Komadan, leaf area which had moderately high heritability and genetic advance was significantly correlated with all seedling characters as compared to all other varieties/types indicating that the selections applied on first and second generation Komadan have increased photosynthetic efficiency which leads to increase in seedling vigour. The low values of standard error show the reliability of the genotypic correlation coefficients in this study (Table 59).

5.4.6. Direct and indirect effects of seednut characters on seedling vigour index

The direct and indirect effects which is also termed as path coefficient analysis proposed by Wright (1921) is an effective means of examining the direct and indirect relationships among plant characters. It is considered to be a standardised partial regression analysis which specifies the relative importance and measures of the direct influence of one variable upon another besides partitioning of the correlation coefficients into direct and indirect effects (Dewey and Lu, 1959). In the present study, 15 seednut characters were considered as the causal factors and seedling vigour index as the effect. Husk/nut ratio and weight of husked nut had the maximum direct effect on seedling vigour index in the three generations of Komadan and in NCD. However in WCT, weight of opened nut was the seednut component which had maximum direct effect on seedling vigour index followed by weight of unhusked nut. It was further observed that most of the characters which had positive direct effect on seedling vigour index in Komadan and NCD were found to exert only negative direct effect in WCT. This indirectly indicates the separate origin of Komadan and its genetic identity over WCT. Similarly between Komadan types and NCD, these relations indicate the probable origin of the former from the latter through limited cycles of artificial selection of seednuts and seedlings.

5.4.7. Genetic divergence in mother palms.

Based on height, number of leaves, girth at collar and total leaf area of seedlings at 9th month after sowing, the 50 mother palms belonging to the five varieties/types used for the present study were subjected to D^2 analysis inorder to classify them into group constellations. The results were presented in Tables 65 and 66. It is interesting to note that all the WCT and NCD palms were found constellated in cluster I while the Komadan palms were seen distributed in all the three clusters. This may be due to the common heritage of NCD and WCT since WCT was the male parent for NCD. As a result,the palms of both the types exhibited minimum divergence and got clustered together (Peter and Rai, 1976). All the first generation Komadan palms which were selected from a single location (Thottapuzhassery) were found constellated in cluster I except one palm. However, all the second generation Komadan palms selected from a single location (Vellayani) were seen distributed in two clusters with a major portion in cluster II. This shows that palms selected from same location fell into different clusters which is in agreement with the findings of Bavappa and Mathew (1982) and Markose (1984). As expected the third generation Komadan palms selected from different locations which had its origin from the second generation Komadan palms, were seen distributed in all the three clusters. Similar results on genetic divergence in coconut were reported by Balakrishnan and Namboodiri (1987). This indicates the comparative unstable genetic identity of Komadan as against WCT and NCD. This is an expected phenomenon since the hypothesis on the origin of Komadan stands accepted from the various other results.

In view of the objective of this study, it can be concluded that the three Komadan generations showed significant superiority over WCT and NCD regarding three mother palm characters viz., number of leaves, number of bunches and spadices and number of nuts per palm per year. Moreover, the three Komadan generations were significantly superior to WCT with respect to 11 seednut characters viz., equatorial diameter of nut, weight of unhusked nut, weight of husked nut, weight of opened nut, volume of nut water, thickness of meat, diameter of eye, weight of embryo, weight of shell, weight of kernel and weight of copra. Oil content in the Komadan types were found to be on par with WCT, where WCT has already been reported to be superior in oil content. However, the thickness of meat in the Komadan types were superior to both WCT and NCD. These results clearly indicate the superiority of Komadan coconut type in relation to the economically important characters viz., nut yield per palm per year, weight of husked nut, weight of kernel, weight of copra and oil content.

Regarding the seedling characters also, though one or the other of the Komadan generation was found to be on par with NCD, all the three Komadan generations were found to be significantly superior to WCT. The important seedling characters viz., number of leaves, girth at collar, total leaf area, seedling vigour index, number of seedlings with split leaves and recovery of quality seedlings showed significant superior values in the Komadan types compared to

WCT. With regard to total leaf area, the three Komadan generations behaved as a distinct type compared to both WCT and NCD.

The points highlighted above clearly denote the definite superiority of Komadan over WCT and NCD even though it was on par with NCD for certain characters since the Komadan has its origin from NCD through artificial selection by farmers in the centre of origin.

The three Komadan generations were considered for the study to have a knowledge on the genetic identity of this type over generations. From this study, it is clear that the three Komadan generations maintained their genetic identity for number of leaves and number of bunches and spadices in the case of mother palm characters. This type maintained its genetic identity in several seednut characters also viz., equatorial diameter of nut, thickness of husk, weight of unhusked nut, weight of husked nut, volume of nut water, thickness of meat, diameter of eye, weight of embryo, weight of kernel, weight of copra and oil content. This indicates that the Komadan type maintained its genetic identity with respect to the economically important characters viz., kernel, copra and oil content. However, regarding seedling characters, it maintained its identity in the recovery of quality seedlings which in turn reflects on the prepotent nature of the mother palm. It is also important from the farmer's point of view since quality seedlings are being recommended for cultivation as one of the measures for increasing productivity in coconut.

The collection and maintenance of typical Komadan germplasm through *inter se* crossing and development of isolated seed gardens for large scale production of Komadan seedlings are suggested as future line of work.

SUMMARY

SUMMARY

A local coconut type called Komadan is very popular in the Central Travancore region of Kerala for the last many decades. However, not much is known about its genetic status in relation to its origin. The present study was undertaken to make a comparison of Komadan with WCT and NCD types through fruit component and seedling progeny analysis with a view to unravel the genetic status of Komadan.

The experiment was conducted in the Department of Plant Breeding, College of Agriculture, Vellayani during the period from October 1988 to August 1990. The material consisted of mother palms pertaining to three different generations of Komadan including the oldest ones from its centre of origin. They were compared with West Coast Tall (WCT) palms having similar yield range and age group available in the Instructional Farm, Vellayani and Natural Cross Dwarf (NCD) palms maintained at Regional Agricultural Research Station, Pilicode, Kasaragod district. The data on mother palm, seednut and seedling characters of these five varieties/types were subjected to statistical analysis. Selfing of these mother palms was also done and the selfed nuts were compared with the open pollinated nuts to detect

the extent of inbreeding in each variety/type. The results obtained were as follows.

1. Variation was noticed among the five varieties/types for five mother palm characters viz., number of leaves, number of bunches and spadices, number of nuts per bunch, number of female flowers per bunch and number of nuts per palm per year.

2. Komadan types showed significant superiority for majority of the mother palm characters especially number of bunches and spadices and number of nuts per palm per year.

3. Medium to high phenotypic and genotypic coefficients of variation were observed for number of nuts per palm per year, number of female flowers per bunch and number of nuts per bunch indicating scope for selection based on these characters.

4. High heritability combined with moderate to high genetic advance were recorded for nut yield per palm per year and number of female flowers per bunch indicating the predominance of additive genes for these characters.

5. The correlation studies among mother palm characters have not shown any distinct pattern for the Komadan types compared to WCT and NCD. The second generation Komadan has shown significant positive correlation individually for number of bunches and spadices with number of nuts per bunch, number of female flowers per bunch and number of nuts per palm per year.

6. Among the three types of Komadan, 33 per cent of the palms showed self-pollinating nature while all the NCD palms were highly self pollinators and WCT palms highly cross pollinators. This shows that the Komadan types occupy a position in between NCD and WCT regarding pollination system.

7. In the first, second and third generation Komadan, one, three and two palms respectively were intermediate in bearing habit;in second generation Komadan three palms showed alternate bearing habit while the remaining palms in all the three generations were regular bearers. In WCT, four palms were regular bearers while the remaining ones were intermediate. In NCD all the palms except one were alternate bearers of varying degrees.

8. Variability for leaf stalk colour of mother palms was very low where 90 per cent of the palms exhibited olive shade while only 10 per cent showed variation for this character in all the varieties/types.

9. Significant variation was noticed for nut colour in the different varieties/types where all the Komadan palms under the three groups had nuts of different shades of brown colour while 70 per cent of WCT palms had nuts of green shades. NCD types had nuts of varying shades of green, olive and brown. This character indicates the distinction of Komadan as a separate group against WCT and NCD.

10. The Komadan types were significantly superior to WCT in all seednut characters except oil content, thickness of husk and husk/nut ratio where as NCD was found to be on par with Komadan for most of the seednut characters.

11. The three Komadan generations showed significant superiority for thickness of meat and behaved as a distinct type over NCD and WCT and this might have influenced the increase in kernel and copra weights of Komadan considerably.

12. In the scatter diagram where the individual mother palms were plotted against percentage of husk and weight of unhusked nut it was seen that these parameters for WCT match closely to those of the primitive Niu kafa and for NCD towards the highly evolved Niu vai. The three Komadan generations accommodated themselves in an area midway between NCD and WCT with a clear progression through generations towards better weight of unhusked nut.

13. The Komadan type maintained its genetic identity over generations in several seednut characters viz., equatorial diameter of nut, thickness of husk, weight of unhusked nut, weight of husked nut, volume of nut water, thickness of meat, diameter of eye, weight of embryo, weight of kernel, weight of copra and oil content.

14. Moderate to high phenotypic and genotypic coefficients of variation were observed for volume of nut water, weight of unhusked nut, husked nut, shell, kernel and copra indicating the high genetic variability for these characters.

15. High heritability and genetic advance were noticed for husk/nut ratio, weight of husked nut, opened nut, embryo,

shell, kernel and copra. The definite superiority of Komadan group over WCT in these characters indirectly proves its prepotent nature.

16. Significant positive correlation was noticed for thickness of meat with kernel and copra in the Komadan types. But this type of correlation was absent in WCT and NCD.

17. Significant reduction in embryo and kernel weight in selfed nuts of NCD and WCT indicated a high degree of inbreeding depression and also the heterozygous nature of these genotypes. In Komadan there was insignificant reduction in the weight of embryo and a significant increase in weight of kernel in the selfed nuts compared to the open pollinated ones indicating lack of inbreeding depression and high degree of homozygosity.

18. Germination percentage was highest in first generation Komadan while the seednuts of second and third generation Komadan types have shown significant early germination compared to WCT and NCD.

19. In all the seedling characters observed at various stages of growth, the Komadan group showed significant

superiority over WCT except in the case of chlorophyll content at 5th month and chlorophyll `b' at 9th month after germination.

20. The Komadan types behaved as a distinct group with regard to total leaf area over both WCT and NCD at 5th and 9th months after germination. They were also found significantly superior to WCT for seedling vigour index.

21. The Komadan group showed significant superiority over WCT in increment in leaf production, the critical seedling character that determines photosynthetic efficiency. The second generation Komadan showed significant superiority in total increment in leaf area during this period over all other varieties/types.

22. Seedling characters observed at 12th month after sowing showed significant superiority of Komadan types over WCT. The three Komadan generations were superior to WCT in producing more number of seedlings with split leaves.

23. The three Komadan types were on par regarding recovery of quality seedlings and were significantly superior to WCT. Based on this character 20 per cent of the palms in both WCT

and NCD and 40 to 60 per cent of the palms in Komadan types were identified to be prepotent.

24. Analysis of petiole colour of seedlings showed that 71 to 82 per cent of seedlings among the three Komadan generations showed moderate brown colour (bronze);97 per cent of WCT seedlings had different shades of green and wider variations in petiole colour were noticed in NCD seedlings.

25. The present results on petiole colour indicate the possibility of inclusion of one more character namely bronze colour of petiole in the selection of quality seedlings in coconut.

26. Genotypic coefficient of variation was highest for number of seedlings with split leaves in all the varieties/types. Moderate values for genotypic coefficient of variation were noticed for germination aspects and recovery of quality seedlings in the three Komadan types and NCD while only recovery of quality seedlings exhibited moderate values in WCT.

27. In the three Komadan generations and in NCD heritability and genetic advance were moderate to high for

germination of seednuts and recovery of quality seedlings indicating the predominance of additive genes. In WCT, selection on the basis of germination of seednuts is not effective due to low heritability and genetic advance.

28. Most of the seednut characters which had positive direct effect on seedling vigour index in Komadan and NCD exerted only negative direct effect in WCT indicating indirectly the separate origin of Komadan and its genetic identity over WCT.

29. All the WCT and NCD palms were found constellated in cluster I which may be due to the common heritage. The Komadan palms belonging to the three generations were seen distributed in all the three clusters indicating the comparative unstable genetic identity of Komadan as against WCT and NCD.

The results achieved from this study clearly indicate the superiority of Komadan coconut type in relation to the economically important characters viz. nut yield per palm per year, weight of husked nut, weight of kernel, weight of copra and oil content. Moreover, the three Komadan generations also maintained their genetic identity for most of the economically important characters as well as in the recovery of quality seedlings which in turn reflects on the prepotent nature of the mother palms.

The collection and maintenance of typical Komadan germplasm through *inter se* crossing and development of isolated seed gardens for large scale production of Komadan seedlings are suggested as future line of work.

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* Original not seen

APPENDICES

D2 VALUES

	1	2	3	4	5	6	7	8	9	10	
1	0.00	564530.80	17612.68	17775.62	1469716.00	152474.90	171397.00	201230.70	6687.28	465384.50	1
2	564530.80	0.00	781570.40	381967.60	3856005.00	130229.10	1358047.00	1439855.00	448341.60	4784.66	2
3	17612.68	781570.40	0.00	70775.06	1165552.00	273730.70	79124.04	99777.45	46004.56	664067.20	3
4	17775.62	381967.60	70775.06	0.00	1810740.00	66134.13	299563.00	338618.70	2657.63	301259.80	4
5	1469716.00	3856005.00	1165552.00	1810740.00	0.00	2568965.00	637315.30	583228.40	1674666.00	3589163.00	5
6	152474.90	130229.10	273730.70	66134.13	2568966.00	0.00	647188.80	704033.70	95302.71	85096.19	6
7	171397.00	1358047.00	79124.04	299563.00	637315.30	647188.80	0.00	1196.33	245791.30	1201637.00	7
8	201230.70	1439855.00	99777.45	338618.70	583268.40	704033.70	1196.33	0.00	281281.40	1278659.00	8
9	6687.28	448341.60	46004.56	2657.63	1674666.00	95302.71	245791.30	281281.40	0.00	360504.20	9
10	465384.50	4784.66	664067.20	301259.80	3589163.00	85096.19	1201637.00	1278659.00	360504.20	0.00	10
11	1791922.00	344893.50	2164839.00	1452764.00	6507317.00	898984.00	3071704.00	3194135.00	1579687.00	430908.10	11
12	2046015.00	4760001.00	1683969.00	2445188.00	47556.21	3315566.00	1033049.00	963938.20	2286629.00	4462996.00	12
13	3899889.00	1496859.00	4441665.00	3391101.00	10157810.00	2510115.00	5706435.00	5872874.00	3583612.00	1670874.00	13
14	991466.20	59718.20	1273369.00	743742.00	4875450.00	366320.60	1987323.00	2086035.00	835310.40	98303.31	14
15	78350.36	1063505.00	21668.18	170761.30	869384.60	449424.40	17980.38	28451.92	130814.50	925640.20	15
16	1397474.00	185584.70	1728857.00	1100045.00	5733470.00	626738.30	2547689.00	2659296.00	1210832.00	249958.80	16
17	541128.80	250.70	753991.50	362758.00	3794437.00	119119.90	1321616.00	1402334.00	427510.90	2854.37	17
18	1654711.00	286220.40	2013754.00	1329492.00	6243371.00	802594.00	2691213.00	3010027.00	1451025.00	365015.50	18
19	3567469.00	1293729.00	4086408.00	3081626.00	9616777.00	2244886.00	5302771.00	5463258.00	3265265.00	1455846.00	19
20	45150.62	290379.90	119162.50	6267.39	2030065.00	31663.57	392486.30	437018.30	17086.28	220623.30	20
21	43588.40	921849.70	5787.06	117030.00	1007095.00	359110.20	42119.31	57511.04	84417.99	793822.80	21
22	15743740.00	10345780.00	16814510.00	14703530.00	26834020.00	12797490.00	19200500.00	19504810.00	15101520.00	10795480.00	22
23	451987.70	2026787.00	291155.80	649025.10	291620.90	1129502.00	66719.41	50047.94	568624.00	1834646.00	23
24	731494.40	2581250.00	522097.20	977318.80	127481.30	1551904.00	194723.90	165395.50	878053.60	2363799.00	24
25	2326363.00	5182881.00	1939140.00	2750831.00	97927.30	3669990.00	1234858.00	1159186.00	2582493.00	4872760.00	25
26	168750.60	115981.40	295397.10	76993.06	2634489.00	413.16	680283.90	738533.50	106256.60	73657.63	26
27	1572572.00	252677.20	1923033.00	1255979.00	6082839.00	745705.70	2782300.00	2898879.00	1374177.00	326993.60	27
28	1133680.00	3298204.00	868683.70	1435362.00	21785.90	2117675.00	423466.60	379649.00	1314499.00	3051781.00	28
29	158573.40	1321500.00	70491.48	282527.20	662769.50	622036.00	250.36	2538.59	230383.90	1167270.00	29
30	64735.36	1011597.00	14816.18	150354.50	917557.10	415908.20	25463.26	37697.65	113033.90	877259.20	30
31	5259079.00	9269714.00	4668003.00	5888332.00	1168458.00	7202504.00	3531648.00	3402849.00	5640813.00	8853356.00	31
32	4914250.00	8809991.00	4343467.00	5523117.00	1009011.00	6797965.00	3250125.00	3126614.00	5283480.00	8404210.00	32
33	5845199.00	10042800.00	5221099.00	6507628.00	1452916.00	7885787.00	4014749.00	3877344.00	6247281.00	9609227.00	33
34	921249.30	2928101.00	684103.10	1194952.00	63761.50	1823302.00	297916.00	261356.20	1084908.00	2696191.00	34
35	6465983.00	10851630.00	5808667.00	7161781.00	1770269.00	8604304.00	4531913.00	4385851.00	6888531.00	10400760.00	35
36	3757397.00	7234771.00	3260510.00	4292028.00	527200.20	5423686.00	2323798.00	2219545.00	4081096.00	6867500.00	36
37	1645895.00	4138281.00	1322989.00	2005750.00	4988.98	2800281.00	755028.50	696118.30	1362395.00	3861677.00	37
38	1940814.00	4598806.00	1588655.00	2330057.00	32701.01	3181267.00	958696.30	892162.60	2175339.00	4306961.00	38
39	270617.30	1616867.00	150153.60	427103.00	479020.70	829353.70	11280.77	5129.94	362382.00	1445765.00	39
40	1420077.00	3775336.00	1121391.00	1755600.00	429.70	2503199.00	604770.40	552172.20	1621653.00	3511354.00	40
41	1184776.00	3384961.00	913480.60	1492782.00	15340.48	2187305.00	454914.90	409455.20	1369474.00	3135254.00	41
42	3670756.00	7114350.00	3179836.00	4199394.00	495062.40	5319488.00	2255768.00	2153070.00	3990777.00	6750189.00	42
43	2979764.00	6138261.00	2539201.00	3457815.00	264078.50	4480331.00	1721866.00	1632293.00	3268758.00	5800344.00	43
44	2045850.00	4759748.00	1683818.00	2445009.00	47532.52	3315357.00	1032930.00	963823.50	2286456.00	4462753.00	44
45	2906028.00	6032232.00	2471171.00	3378343.00	242447.20	4389812.00	1665928.00	1577840.00	3191504.00	5697281.00	45
46	1133961.00	3298688.00	868931.30	1435674.00	21740.49	2118062.00	423640.70	379813.50	1314799.00	3052243.00	46
47	2773919.00	5841216.00	2349466.00	3235787.00	205386.70	4227089.00	1566272.00	1480897.00	3052988.00	5511693.00	47
48	2035336.00	4743701.00	1674281.00	2433516.00	45946.81	3301968.00	1025462.00	956610.40	2275342.00	4447219.00	48
49	524211.00	2176736.00	349650.80	735039.70	238433.40	1242119.00	96115.12	75866.03	649305.60	1977440.00	49
50	147393.00	1288839.00	63105.42	267535.10	666249.00	599691.80	906.25	4183.33	216865.60	1136566.00	50

D2 VALUES (contd.)

	11	12	13	14	15	16	17	18	19	20	
1	1791922.00	2046015.00	3899889.00	991466.20	78350.36	1397474.00	541128.80	1654711.00	3567469.00	45150.62	1
2	344893.50	4760001.00	1496859.00	59718.20	1063505.00	185584.70	250.70	286229.40	1293729.00	290379.90	2
3	2164839.00	1683969.00	4441665.00	1273369.00	21668.18	1728857.00	753991.50	2013754.00	4086408.00	119162.50	3
4	1452764.00	2445188.00	3391101.00	743742.00	170761.30	1100045.00	362758.00	1329492.00	3081626.00	6267.39	4
5	6507317.00	47556.21	10157810.00	4875450.00	869384.60	5733470.00	3794437.00	6243371.00	9616777.00	2030065.00	5
6	998984.00	3315568.00	2510115.00	366320.60	449424.40	626738.30	119119.90	802594.00	2244886.00	31683.57	6
7	3071704.00	1033049.00	5706435.00	1987323.00	17980.38	2547689.00	1321616.00	2891213.00	5302771.00	392486.30	7
8	3194135.00	963938.20	5872874.00	2086035.00	28451.92	2659296.00	1402334.00	3010027.00	5463258.00	437018.30	8
9	1579687.00	2286629.00	3583612.00	835310.40	130814.50	1210832.00	427510.90	1451025.00	3265265.00	17086.28	9
10	430908.10	4462996.00	1670874.00	98303.31	925640.20	249958.80	2654.37	365015.50	1455846.00	220623.30	10
11	0.00	7667451.00	404734.70	117583.00	2619665.00	24488.78	363624.40	2732.73	302666.90	1268194.00	11
12	7667451.00	0.00	11595410.00	5886027.00	1323601.00	6825355.00	4691571.00	7380706.00	11016850.00	2699038.00	12
13	404734.70	11595410.00	0.00	958617.60	5083785.00	628320.80	1535617.00	473974.70	7405.06	3105802.00	13
14	117583.00	5886027.00	958617.60	0.00	1627245.00	34755.00	67658.35	84466.98	797540.80	613463.20	14
15	2619665.00	1323601.00	5083785.00	1627245.00	0.00	2137617.00	1031292.00	2453192.00	4703197.00	242454.70	15
16	24488.78	6825355.00	628320.80	34755.00	2137617.00	0.00	199396.20	10860.50	499321.00	940247.90	16
17	363624.40	4691571.00	1535617.00	67658.35	1031292.00	199396.20	0.00	303317.50	1329784.00	273663.70	17
18	2732.73	7380706.00	473974.70	84466.98	2453192.00	10860.50	303317.50	0.00	362910.00	1153198.00	18
19	302666.90	11016850.00	7405.06	797540.80	4703197.00	499321.00	1329784.00	362910.00	0.00	2809949.00	19
20	1268194.00	2699038.00	3105802.00	613463.20	242454.70	940247.90	273663.70	1153198.00	2809949.00	0.00	20
21	2394457.00	1492338.00	4768067.00	1450822.00	5061.00	1934673.00	891873.20	2235421.00	4399724.00	177461.50	31
22	6912755.00	29140860.00	3972146.00	8833464.00	18043370.00	7760072.00	10447280.00	7190349.00	4322508.00	14102680.00	22
23	4043828.00	574700.20	7007213.00	2782305.00	153969.40	3438978.00	1982223.00	3836334.00	6559104.00	782846.00	23
24	4813201.00	330757.90	8009399.00	3426194.00	331043.00	4151090.00	2530926.00	4586580.00	7529805.00	1140111.00	24
25	8201744.00	9000.21	12250390.00	6355269.00	1550849.00	7329958.00	5111471.00	7905081.00	11655500.00	3019698.00	25
26	860877.60	3389954.00	2446164.00	342145.50	477071.80	594989.50	105510.70	766611.60	2184431.00	39326.91	26
27	7161.77	7206071.00	519542.60	66719.40	2352952.00	5166.05	268751.80	1047.07	402910.10	1084803.00	27
28	5776191.00	133702.10	9238910.00	4245527.00	615963.20	5048520.00	3241291.00	5527669.00	8723265.00	1631317.00	28
29	3016610.00	1065390.00	5631253.00	1943058.00	13995.32	2497540.00	1285562.00	2837769.00	5230310.00	372951.60	29
30	2537830.00	1382887.00	4969527.00	1562884.00	650.53	2063754.00	980189.60	2374020.00	4593321.00	218012.40	30
31	13190660.00	744562.20	18216530.00	10817470.00	4053607.00	12078510.00	9174127.00	12813710.00	17489480.00	6278801.00	31
32	12641140.00	616461.40	17569720.00	10320380.00	3751581.00	11552920.00	8716813.00	12272180.00	16855820.00	5901481.00	32
33	14109880.00	974756.80	19294040.00	11651360.00	4570076.00	12958790.00	9943293.00	13719910.00	18545590.00	6917796.00	33
34	5282846.00	221441.70	8612059.00	3824142.00	462272.90	4588014.00	2874489.00	5045293.00	8114472.00	1374295.00	34
35	15065710.00	1237527.00	20409100.00	12521360.00	5120801.00	13875450.00	10748190.00	14662660.00	19639110.00	7591763.00	35
36	10736910.00	258079.40	15313250.00	8609066.00	2750588.00	9737820.00	7150354.00	10399060.00	14647260.00	4626311.00	36
37	6872530.00	21748.20	10612850.00	5192237.00	1006035.00	6076580.00	4074498.00	6601200.00	10059670.00	2236251.00	37
38	7462501.00	1394.41	11343050.00	5706627.00	1239259.00	6632057.00	4531557.00	7179647.00	10770890.00	2578006.00	38
39	3455270.00	828433.90	6225136.00	2298052.00	57743.90	2898016.00	1577093.00	3263675.00	5803196.00	536842.50	39
40	6402401.00	56989.72	10026610.00	4764693.00	831304.60	5635010.00	3714424.00	6140612.00	9489135.00	1971653.00	40
41	5890819.00	116908.30	9383732.00	4343881.00	653774.10	5155724.00	3327298.00	5639816.00	8864006.00	1692496.00	41
42	10592090.00	235744.60	15137820.00	8477680.00	2676531.00	9598032.00	7030642.00	10254580.00	14475710.00	4530117.00	42
43	9393158.00	87505.91	13697500.00	7408866.00	2091750.00	8458481.00	6060526.00	9075488.00	13068030.00	3758499.00	43
44	7667133.00	0.85	11595020.00	5885748.00	1323468.00	6825052.00	4691323.00	7350393.00	11016470.00	2698849.00	44
45	9261878.00	75250.60	13538870.00	7292328.00	2030045.00	8333985.00	5955166.00	8946456.00	12913110.00	3675627.00	45
46	5776825.00	133600.40	9239714.00	4246072.00	616170.30	5049119.00	3241765.00	5528292.00	8724052.00	1631651.00	46
47	9024829.00	55283.38	13251950.00	7082158.00	1919881.00	8109146.00	5765392.00	8713502.00	12632920.00	3526863.00	47
48	7646767.00	18.61	11569970.00	5867904.00	1315015.00	6805834.00	4675396.00	7360411.00	10992050.00	2686773.00	48
49	4254528.00	498953.20	7283726.00	2957533.00	197236.30	3633491.00	2130544.00	4041626.00	6826715.00	877049.80	49
50	2967158.00	1095105.00	5563613.00	1903410.00	10817.53	2452562.00	1253350.00	2789812.00	5165130.00	355696.20	50

D2 VALUES (contd)

	21	22	23	24	25	26	27	28	29	30	
1	43588.40	15743740.00	451987.70	731494.40	2326363.00	168750.60	1572572.00	1133680.00	158573.40	64735.36	1
2	921649.70	10345780.00	2026787.00	2581250.00	5182881.00	115981.40	252677.20	3298204.00	1321500.00	1011597.00	2
3	5787.06	16814510.00	291155.80	522097.20	1939140.00	295397.10	1923033.00	868683.70	70491.48	14816.18	3
4	117030.00	14703530.00	649025.10	977318.80	2750831.00	76993.06	1255979.00	1435362.00	282527.20	150354.50	4
5	1007095.00	26834020.00	291620.90	127481.30	97927.30	2634489.00	6082839.00	21785.90	662769.50	917557.10	5
6	359110.20	12797490.00	1129502.00	1551904.00	3669990.00	413.16	745705.70	2117675.00	622036.00	415908.20	6
7	42119.31	19200500.00	66719.41	194723.90	1234858.00	680283.90	2782300.00	423466.60	250.36	25463.26	7
8	57511.04	19504810.00	50047.94	165395.50	1159186.00	736533.50	2696679.00	379649.00	2538 59	37697.65	8
9	84417.99	15101520.00	568624.00	878053.60	2582493.00	108256.60	1374177.00	1314499.00	230383.90	113033.90	9
10	793822.80	10795480.00	1834646.00	2363799.00	4872760.00	73657.63	326993.60	3051781.00	1167270.00	877259.20	10
11	2394457.00	6912755.00	4043828.00	4813201.00	8201744.00	860877.60	7161.77	5776191.00	3016610.00	2537830.00	11
12	1492338.00	29140860.00	574700.20	330757.90	9000.21	3389954.00	7206071.00	133702.10	1065390.00	1382887.00	12
13	4768067.00	3972146.00	7007213.00	8009399.00	12250390.00	2446164.00	519542.60	9238910.00	5631253.00	4969527.00	13
14	1450822.00	8833464.00	2782305.00	3426194.00	6355269.00	342145.50	66719.40	4245527.00	1943058.00	1562864.00	14
15	5061.00	18043370.00	153969.40	331043.00	1550849.00	477071.80	2352952.00	615963.20	13995.32	650.53	15
16	1934673.00	7760072.00	3436978.00	4151090.00	7329958.00	594989.50	5166.05	5048520.00	2497540.00	2063754.00	16
17	891873.20	10447280.00	1982223.00	2530926.00	5111471.00	105510.70	268751.80	3241291.00	1285562.00	980189.60	17
18	2235421.00	7190349.00	3836334.00	4586580.00	7905081.00	766611.60	1047.07	5527669.00	2837769.00	2374020.00	18
19	4399724.00	4322508.00	6559104.00	7529805.00	11655500.00	2184431.00	402910.10	8723265.00	5230310.00	4593321.00	19
20	177461.50	14102680.00	782846.00	1140111.00	3019698.00	39326.91	1084803.00	1631317.00	372951.60	218012.40	20
21	0.00	17444110.00	214855.00	417959.60	1733083.00	383866.90	2139784.00	732683.60	35886.35	2087.96	21
22	17444110.00	0.00	21530880.00	23262410.00	30173930.00	12652570.00	7364797.00	25326880.00	19062400.00	17827550.00	22
23	214855.00	21530880.00	0.00	33479.72	727510.00	1173090.00	3710719.00	154013.30	75124.58	174617.70	23
24	417959.60	23262410.00	33479.72	0.00	448858.30	1602925.00	4449134.00	43880.42	208905.80	361017.40	24
25	1733083.00	30173930.00	727510.00	448858.30	0.00	3748229.00	7724308.00	212059.00	1270197.00	1614964.00	25
26	383866.90	12652570.00	1173090.00	1602925.00	3748229.00	0.00	711037.50	2177207.00	654489.40	442520.60	26
27	2139784.00	7364797.00	3710719.00	4449134.00	7724308.00	711037.50	0.00	5376674.00	2729881.00	2275426.00	27
28	732683.60	25326880.00	154013.30	43880.42	212059.00	2177207.00	5376674.00	0.00	444266.50	656609.10	28
29	35886.35	19062400.00	75124.58	208905.80	1270197.00	654489.40	2729881.00	444266.50	0.00	20675.85	29
30	2087.96	17827550.00	174617.70	361017.40	1614964.00	442520.60	2275426.00	656609.10	20675.85	0.00	30
31	4345108.00	39201450.00	2627537.00	2067828.00	589865.60	7311943.00	12583270.00	1509274.00	3591238.00	4156865.00	31
32	4032203.00	38249880.00	2385514.00	1853783.00	478268.10	6904298.00	12046680.00	1327260.00	3307303.00	3850942.00	32
33	4879278.00	40774900.00	3046367.00	2441129.00	796454.50	8000280.00	13481430.00	1830450.00	4078271.00	4679673.00	33
34	564064.50	24281790.00	82666.60	10930.99	319705.30	1878570.00	4901085.00	11009.88	315401.70	497572.40	34
35	5447808.00	42388790.00	3498881.00	2847845.00	1035485.00	8723883.00	14416080.00	2184739.00	4599386.00	5236776.00	35
36	2991601.00	34863650.00	1603011.00	1173165.00	170702.60	5518707.00	10191560.00	763279.20	2372183.00	2835761.00	36
37	1153795.00	27570510.00	372861.70	182885.50	58718.12	2868676.00	6436098.00	47603.64	782716.20	1057802.00	37
38	1402699.00	28739980.00	519598.00	289293.20	17454.45	3254138.00	7007417.00	107838.60	989865.80	1296640.00	38
39	96992.56	20142570.00	23133.00	112271.60	1010093.00	866762.40	3147894.00	296519 10	14885.24	70638.93	39
40	966080.80	26620530.00	269745.10	113163.40	111271.10	2567885.00	5981411.00	16111.67	629576.50	878420.90	40
41	773869.00	25566300.00	173200.70	54383.04	190766.70	2247200.00	5487289.00	564.20	476462.20	695631.40	41
42	2914346.00	34618630.00	1546594.00	1124975.00	152631.70	5413597.00	10048540.00	724505.50	2303443.00	2760557.00	42
43	2302573.00	32422060.00	1110703.00	758511.60	40384.18	4566734.00	8881719.00	437524.50	1763551.00	2166107.00	43
44	1492199.00	29140250.00	574612.30	330691.90	9008.71	3389740.00	7205759.00	133657.00	1065272.00	1382750.00	44
45	2237808.00	32177770.00	1065865.00	721536.90	32213.39	4475340.00	8754084.00	409560.90	1706930.00	2103312.00	45
46	732906.70	25328210.00	154116.30	43932.98	211939.00	2177599.00	5377292.00	3.84	444440.70	656827.30	46
47	2122071.00	31734600.00	986462.90	656480.90	19674.82	4311026.00	8523659.00	360919.10	1606041.00	1991145.00	47
48	1483224.00	29100520.00	569047.50	326475.00	9720.18	3376201.00	7186012.00	130977.70	1057690.00	1374105.00	48
49	265480.70	22013570.00	2675.62	17226.87	641951.10	1287809.00	3912668.00	116091.80	106153.40	220520.90	49
50	30674.76	18937770.00	83165.19	222177.50	1302624.00	631564.60	2682848.00	463527.20	204.36	16769.70	50

D2 VALUES (contd.)

	31	32	33	34	35	36	37	38	39	40	
1	5259079.00	4914250.00	5845199.00	921249.30	6465983.00	3757397.00	1645895.00	1940814.00	270617.30	1420077.00	1
2	9269714.00	8609991.00	10042800.00	2928101.00	10851630.00	7234771.00	4138281.00	4598806.00	1616867.00	3775336.00	2
3	4668003.00	4343467.00	5221099.00	684103.10	5808667.00	3260510.00	1322939.00	1588655.00	150153.60	1121381.00	3
4	5888332.00	5523117.00	6507628.00	1194952.00	7161781.00	4292028.00	2005750.00	2330057.00	427103.00	1755600.00	4
5	1168458.00	1009011.00	1452916.00	63761.50	1770269.00	527200.20	4988.98	32701.01	479020.70	429.70	5
6	7202504.00	6797965.00	7885787.00	1823302.00	8604304.00	5423686.00	2800261.00	3161267.00	829353.70	2503199.00	6
7	3531640.00	3250125.00	4014749.00	297916.00	4531913.00	2323798.00	755028.50	958696.30	11280.77	604770.40	7
8	3402849.00	3126614.00	3877344.00	261356.20	4385851.00	2219545.00	696118.30	892162.60	5129.94	552172.20	8
9	5640813.00	5283480.00	6247281.00	1084908.00	6888531.00	4081096.00	1862395.00	2175339.00	362382.00	1621653.00	9
10	8853356.00	8404210.00	9609227.00	2696191.00	10400760.00	6867500.00	3861677.00	4306961.00	1445765.00	3511354.00	10
11	13190660.00	12641140.00	14109880.00	5282846.00	15065710.00	10738910.00	6872530.00	7462501.00	3455270.00	6402401.00	11
12	744562.20	618461.40	974756.80	221441.70	1237527.00	258079.40	21746.20	1394.41	826433.90	56989.72	12
13	18216530.00	17569720.00	19294040.00	8612059.00	20409100.00	15313250.00	10612850.00	11343050.00	6225136.00	10026610.00	13
14	10817470.00	10320380.00	11651360.00	3824142.00	12521360.00	8609066.00	5192237.00	5706627.00	2298052.00	4784693.00	14
15	4053607.00	3751581.00	4570076.00	462272.90	5120801.00	2750588.00	1006035.00	1239259.00	57743.90	831304.60	15
16	12078510.00	11552920.00	12958790.00	4588014.00	13875450.00	9737820.00	6076580.00	6632057.00	2698016.00	5635010.00	16
17	9174127.00	8716813.00	9943293.00	2874489.00	10748190.00	7150354.00	4074498.00	4531557.00	1577093.00	3714424.00	17
18	12813710.00	12272180.00	13719910.00	5045293.00	14662660.00	10399060.00	6601200.00	7179647.00	3263675.00	6140612.00	18
19	17489480.00	16855820.00	18545590.00	8114472.00	19639110.00	14647260.00	10059670.00	10770890 00	5803196.00	9489135.00	19
20	6278801.00	5901481.00	6917796.00	1374295.00	7591763.00	4626311.00	2236251.00	2576006 00	536842.50	1971653.00	20
21	4345108.00	4032203.00	4879278.00	564064.50	5447802.00	2991601.00	1153795.00	1402699.00	96992.56	966080.80	21
22	39201450.00	38249880.00	40774900.00	24261790.00	42388790.00	34663650.00	27570510.00	28739980.00	20142570.00	26620530.00	22
23	2627537.00	2385514.00	3046367.00	82666.60	3498881.00	1603011.00	372861.70	519598.00	23133.00	269745.10	23
24	2067828.00	1653783.00	2441129.00	10930.99	2847645.00	1173165.00	182885.50	289293.20	112271.60	113163.40	24
25	589865.60	478268.10	796454.50	319705.30	1035485.00	170702.60	58718.12	17454.45	1010093.00	111271.10	25
26	7311943.00	6904298.00	8000280.00	1878570.00	8723883.00	5518707.00	2868676.00	3254138.00	866762.40	2567885.00	26
27	12583270.00	12046680.00	13481430.00	4901085.00	14416080.00	10191560.00	6436098.00	7007417.00	3147894.00	5981411.00	27
28	1500274.00	1327260.00	1830450.00	11009.88	2184739.00	763279.20	47603.64	107838.60	296519.10	16111.67	28
29	3591238.00	3307303.00	4078271.00	315401.70	4599386.00	2372183.00	782716.20	989865.80	14825.24	629576.50	29
30	4156865.00	3850942.00	4679673.00	497572.40	5236776.00	2835761.00	1057802.00	1296640.00	70638.93	878420.90	30
31	0.00	5845.91	15480.18	1778092.00	62281.77	125931.60	1020796.00	810249.10	3143741.00	1213519.00	31
32	5845.91	0.00	40350.63	1580032.00	106288.60	77513.26	872144.10	678449.90	2878460.00	1050914.00	32
33	15480.18	40350.63	0.00	2125377.00	15661.74	229714.10	1287682.00	1049710.00	3600415.00	1503112.00	33
34	1778092.00	1580032.00	2125377.00	0.00	2505928.00	957626.20	104398.30	187760.70	193256.10	53755.97	34
35	62281.77	106288.60	15661.74	2505928.00	0.00	365336.70	1587362.00	1321808.00	4090997.00	1825633.00	35
36	125931.60	77513.26	229714.10	957626.20	365336.70	0.00	429650.30	297320.70	2011269.00	557606.80	36
37	1020796.00	872144.10	1287682.00	104398.30	1587362.00	429650.30	0.00	12146.42	581735.90	8327.57	37
38	810249.10	678449.90	1049710.00	187760.70	1321808.00	297320.70	12146.42	0.00	761993.10	40587.23	38
39	3143741.00	2878460.00	3600415.00	193256.10	4090997.00	2011269.00	581735.90	761993.10	0.00	450860.90	39
40	1213519.00	1050914.00	1503112.00	53755.97	1825633.00	557606.80	8327.57	40587.23	450860.90	0.00	40
41	1451530.00	1273144.00	1766801.00	16552.77	2115151.00	722375.80	37810.93	92816.58	322926.20	10649.42	41
42	142390.50	90534.45	251766.30	914135.80	393014.50	505.55	400685.90	273311.40	1948015.00	524540.50	42
43	321567.50	240699.70	478152.10	587341.50	666885.30	45030.56	196492.70	110935.70	1454414.00	285721.90	43
44	744659.30	618549.30	974866.40	221385.10	1237652.00	258135.30	21729.41	1386.44	828326.60	56960.35	44
45	346408.00	262255.00	508344.60	554865.80	702456.50	54617.17	177904.30	97087.91	1403042.00	263210.50	45
46	1508949.00	1326957.00	1830096.00	11039.87	2184350.00	763049.00	47546.64	107756.20	296666.10	16078.90	46
47	394083.10	303934.60	565769.60	498000.60	769692.60	74472.45	146371.00	74191.34	1311714.00	224523.90	47
48	751026.20	624352.40	962146.90	217935.00	1245854.00	261890.40	20658.45	1124.83	821640.40	55218.13	48
49	2462530.00	2228415.00	2868489.00	55599.73	3308056.00	1474713.00	312370.30	447706.70	41542.72	218694.10	49
50	3645623.00	3359500.00	4136212.00	331662.60	4660905.00	2416421.00	808214.50	1018515.00	18577.73	652465.80	50

D2 VALUES (contd)

	41	42	43	44	45	46	47	48	49	50	
1	1184776.00	3670756.00	2979764.00	2045850.00	2906028.00	1133961.00	2773919.00	2035336.00	524211.00	147393 00	1
2	3384961.00	7114350.00	6138261.00	4759748.00	6032232.00	3298688.00	5841216.00	4743701.00	2176736.00	1288839.00	2
3	913480.60	3179836.00	2539201.00	1683818.00	2471171.00	868931.30	2349466.00	1674281.00	349650.80	63105.42	3
4	1492782.00	4199394.00	3457615.00	2445009.00	3378343.00	1435674.00	3235787.00	2433516.00	735039.70	267535.10	4
5	15340.48	495062.40	264078.50	47532.52	242447.20	21740.49	205386.70	45946.81	238433.40	686249.00	5
6	2187305.00	5319468.00	4460331.00	3315357.00	4389812.00	2118062.00	4227089.00	3301968.00	1242119.00	599691.60	6
7	454914.90	2255768.00	1721866.00	1032930.00	1665928.00	423640.70	1566272.00	1025462.00	96115.12	906.25	7
8	409455.20	2153070.00	1632293.00	963823.50	1577640.00	379813.50	1480897.00	956610.40	75866.03	4183.33	8
9	1369474.00	3990777.00	3268758.00	2286456.00	3191504.00	1314799.00	3052928.00	2275342.00	649305.60	216865.60	9
10	3135254.00	6750189.00	5800344.00	4462753.00	5697281.00	3052243.00	5511693.00	4447219.00	1977440.00	1136556.00	10
11	5890819.00	10592090.00	9393158.00	7667133.00	9261878.00	5776825.00	9024829.00	7646767.00	4254528.00	2967158 00	11
12	116908.30	235744.60	87505.91	0.85	75250.60	133600.40	55283.38	16.61	498953.20	1095105.00	12
13	9383732.00	15137820.00	13697500.00	11595020.00	13538870.00	9239714.00	13251950.00	11569970.00	7283726.00	5563613.00	13
14	4343881.00	8477680.00	7408866.00	5885748.00	7292328.00	4246072.00	7082158.00	5867904.00	2957533 00	1903410.00	14
15	653774.10	2676531.00	2091750.00	1323468.00	2030045.00	616170.30	1919881.00	1315015.00	197236.30	10817.53	15
16	5155724.00	9598032.00	8458481.00	6825052.00	8333935.00	5049119.00	8109146.00	6805834.00	3633491.00	2452562.00	16
17	3327298.00	7030642.00	6060526.00	4691323.00	5955166.00	3241765 00	5765392.00	4675396.00	2130544.00	1253350.00	17
18	5639816.00	10254580.00	9075486.00	7380393.00	8946456.00	5526292.00	8713502.00	7360411.00	4041626.00	2769812.00	18
19	8864006.00	14475710.00	13068030.00	11016470.00	12913110.00	8724052.00	12632920.00	10992050.00	6826715.00	5165130.00	19
20	1692496.00	4530117.00	3758499.00	2698849.00	3675627.00	1631651.00	3526863.00	2686773.00	877049.80	355696.20	20
21	773869.00	2914346.00	2302573.00	1492199.00	2237808.00	732906.70	2122071.00	1483224.00	265480.70	30674.76	21
22	25566300.00	34618630.00	32422060.00	29140250.00	32177770.00	25328210.00	31734600.00	29100520.00	22013570.00	18937770.00	22
23	173200.70	1546594.00	1110703.00	574612.30	1065865.00	154116.30	986462.90	569047.50	2675.62	83165.19	23
24	54383.04	1124975.00	758511.60	330691.90	721536.90	43932.98	656480.90	326475.00	17226.87	222177.50	24
25	190766.70	152631.70	40384.18	9008.71	32213.39	211939.00	19674.82	9720.18	641951.10	1302624.00	25
26	2247800.00	5413597.00	4566734.00	3389740.00	4475340.00	2177599.00	4311026.00	3376201.00	1287809.00	631564.60	26
27	5487289.00	10048540.00	8881719.00	7205759.00	8754084.00	5377292.00	8523659.00	7186012.00	3912668.00	2682848.00	27
28	564.20	724505.50	437524.50	133657.00	409560.90	3.84	360919.10	130977.70	116091.80	463527.20	28
29	476462.20	2303443.00	1763551.00	1065272.00	1706930.00	444440.70	1606041.00	1057690.00	106153.40	204.36	29
30	695631.40	2760557.00	2166107.00	1362750.00	2103312.00	656827.30	1991145.00	1374105.00	220520.90	16769.70	30
31	1451530.00	142390.50	321567.50	744659.30	346408.00	1508949.00	394083.10	751026.20	2462530.00	3645623.00	31
32	1273144.00	90534.45	240699.70	618549.30	262255.00	1326957.00	303934.60	624352.40	2228415.00	3359500.00	32
33	1766801.00	251766.30	478152.10	974866.40	508344.60	1830096.00	565769.60	982146.90	2868489.00	4136212.00	33
34	16552.77	914135.60	567341.50	221385.10	554865.80	11030.87	498000.60	217935.00	55599.73	331662.60	34
35	2115151.00	393014.50	666885.30	1237652.00	702456.50	2184350.00	769692.60	1245854.00	3308056.00	4660905.00	35
36	722375.80	505.65	45030.56	258135.30	54617.17	763049.00	74472.45	261890.40	1474713.00	2416421 00	36
37	37810.93	400685.90	196492.70	21729.41	177904.30	47546.64	146371.00	20658.45	312370.30	808214.50	37
38	92816.58	273311.40	110935.70	1386.44	97087.91	107756.20	74191.24	1124.83	447706.70	1018515.00	38
39	322926.20	1948015.00	1454414.00	828326.60	1403042.00	296666.10	1311714.00	821640.40	41542.72	18577.73	39
40	10649.48	524540.50	285721.90	56960.35	263210.50	16078.90	224523.90	55218.13	218694.10	652465.80	40
41	0.00	684669.60	406693.60	116867.40	379746.20	558.44	332969.20	114365.40	132824.70	496401.30	41
42	684669.60	0.00	35994.82	235798.00	44615.81	724281.40	62707.66	239386.90	1420621.00	2347040.00	42
43	406693.60	35994.82	0.00	87537.78	466.05	437350.50	3683.58	89729.59	1004356.00	1801722.00	43
44	116667.40	235798.00	87537.78	0.00	75283.56	133558.80	55308.42	15.26	498871.50	1094984.00	44
45	379746.20	44615.81	466.05	75283.56	0.00	409384.80	1541.18	77322.36	961741.40	1744487.00	45
46	558.44	724281.40	437350.50	133558.80	409384.80	0.00	360761.10	130885.10	116180.50	463704.80	46
47	332969.20	62707.66	3683.58	55308.42	1541.18	360761.10	0.00	57053.01	886393.90	1642477.00	47
48	114365.40	239386.90	69729.59	15.28	77322.36	130685.10	57053.01	0.00	493687.40	1087298.00	48
49	132824.70	1420621.00	1004356.00	498871.50	961741.40	116180.50	886393.90	493687.40	0.00	115672.60	49
50	496401.30	2347040.00	1801722.00	1094984.00	1744487.00	463704.80	1642477.00	1087298.00	115672.60	0.00	50

FRUIT COMPONENT AND SEEDLING PROGENY ANALYSIS OF KOMADAN COCONUT TYPES

By

P. MANJU, M.Sc. (Ag.)

ABSTRACT OF A THESIS
submitted in partial fulfilment of
the requirement for the degree
DOCTOR OF PHILOSOPHY
Faculty of Agriculture
Kerala Agricultural University

Department of Plant Breeding
COLLEGE OF AGRICULTURE
Vellayani, Thiruvananthapuram

1992

ABSTRACT

The present study was undertaken with a view to unravel the genetic status of a coconut type, Komadan, popular in the Central Travancore region of Kerala, in relation to its origin by comparing its three generations with WCT and NCD through fruit component and seedling progeny analysis.

The study revealed that the Komadan types showed significant superiority for majority of the mother palm characters especially number of bunches and spadices and number of nuts per palm per year. Number of nuts per palm per year and number of female flowers per bunch had high heritability combined with moderate to high genetic advance indicating the predominance of additive genes. Among the Komadan palms, 33 per cent were of self pollinating nature thereby occupying a position in between WCT and NCD regarding pollination system. All the Komadan palms had nuts of different shades of brown while 70 per cent of WCT palms had nuts of green shade and NCD palms had varying shades of green, olive and brown nuts indicating the distinction of Komadan as a separate group.

Estimation of prepotency based on recovery of quality seedlings showed that 40 to 60 per cent of Komadan palms were prepotent where as the same in WCT and NCD were only about 20 per cent.

Analysis of petiole colour of seedlings showed that 71 to 82 per cent of seedlings among the three Komadan generations showed moderate brown colour (bronze) ; 97 per cent of WCT seedlings had different shades of green and wider variations in petiole colour were noticed in NCD seedlings.

It can be concluded that the Komadan type maintained its genetic identity over generations with respect to economically important characters viz. kernel, copra, and oil content and also in the recovery of quality seedlings which inturn reflects its prepotent nature.

The collection and maintenance of typical Komadan germplasm through inter se crossing and development of isolated seed gardens for large scale production of Komadan seedlings are suggested as future line of work.

Komadan types were superior to WCT in all seednut characters except polar diameter of nut, oil content, thickness of husk and husk/nut ratio. It behaved as a distinct type regarding thickness of meat. One or the other of the Komadan generations was found to be on par with NCD for majority of the seednut characters. Komadan types occupied an area midway between NCD and WCT based on Niu kafa-Niu vai Introgression hypothesis with a clear progression through generations towards better weight of unhusked nut.

Inbreeding depression was noticed in WCT and NCD as indicated by significant reduction in embryo and kernel weight in selfed nuts compared to open pollinated nuts. In Komadan there was no inbreeding depression indicating a high degree of homozygosity.

The seednuts of Komadan types showed early germination compared to WCT and NCD.

Regarding seedling characters, Komadan behaved as a distinct type for total leaf area over both WCT and NCD. Number of seedlings with split leaves was also more in Komadan. This type was superior to WCT for seedling vigour index also.